INSTITUTE OF MARINE ENGINEERS
INCORPORATED.

Patron: HIS MAJESTY THE KING.

SESSION 1921-22.

President: SIR JOSEPH P. MACLAY, BART.

VOLUME XXXIII.

The Problem of Grey Iron Castings.

By H. J. YOUNG, F.I.C.

READ

On Tuesday, December 13, 1921, *at* 6.30 *p.m.*

CHAIRMAN: MR. J. CLARK (Member of Council).

DISCUSSION, TUESDAY, JANUARY 24TH, 1922, 6.30 P.M.

LONG before scientific control was thought of, or needed, the industry of ironfounding was carried on by rule-of-thumb methods — and very little change is to be observed in the majority of iron foundries in this country to-day.

What engineering owes to cast iron can be reckoned in terms of what engineering would be now if cast iron had never been, but while the engineer has used every possible resource of academic and applied science to the end of making his structures capable of greater things he has neglected the material that rendered most of those structures commercially possible, namely, cast iron.

Modern foundrywork is the sum total of thousands of little alterations by past generations of workers. Hundreds of men of widely different experience, education and calibre have contributed to these alterations, day by day and year by year, until now; the result being a trade wonderful in its empirical experience and behind all other trades in its scientific knowledge.

Without demand for science there has been little supply, and the building-up process has necessarily gone on without it. Thus have safety factors, thicknesses, rule-of-thumb mixtures, belief in certain pig irons, specifications of testbars and so forth been adopted and established to the degree of being almost beyond the criticism of those in power in most works.

That the ironfoundry trade will eventually walk in the paths of progress nobody doubts, also it may happen that sudden convulsive evolutions will occur as have occurred in the past in many other industries, for example, steel making and soap manufacturing. New materials are wanted to meet new conditions; an unscientific trade is being asked to cater for a scientific one; the engineer has, with one hand, locked his door against metallurgical science while, with the other, he has welcomed and embraced the science of engineering. He is now, in consequence, in the unfortunate position of having the latter asking for more than the former knows how to give.

Two instances alone should be sufficient to convince anyone as yet sceptical. The engineer uses a safety factor for cast iron regardless of whether it may be eight, twelve or sixteen ton metal; he has deliberately agreed to look upon cast iron as an unreliable material. The second instance is that of the engineers' acceptance of the rule-of-thumb mixture. It is well-known that pig irons vary from consignment to consignment yet, no matter whether he has been a maker, buyer or user, the engineer has shut his eyes to the fact that by no possible conjuring could the rule-of-thumb mixture give him metal of known or standard quality.

A consignment of any ordinary pig iron is little more homogeneous than one of mixed scrap. Out of many hundreds of consignments of different brands the author has not found an exception. In Table I. are given some typical examples of the silicon-content found by analysing separate pigs taken from any one consignment of a No. 3 pig iron.

The table shows that no two consignments possess similar or equal variations, that it is impossible to predict the composition or to strike a reliable average. That this is so, is recognised by the makers and sellers of pig iron, who will exploit the wonderful properties of their irons but, in the same breath or on the same paper, will disclaim any responsibility or guarantee for the iron they supply having the same composition as the iron they advertise and recommend. To purchase an iron upon its published composition is to buy a pig in a poke.

TABLE I.

Weight. Date.	350 tons. April 4th, 1920.	280 tons. May 4th, 1920.	280 tons. June 6th, 1920.
Sample of	% Silicon	% Silicon	% Silicon
One pig	2·1	2·4	2·0
another pig	2·2	2·4	2·0
,, ,,	2·2	2·6	2·1
,, ,,	2·3	2·6	2·3
,, ,,	2·3	2·7	2·6
,, ,,	2·3	2·8	2·6
,, ,,	2·3	2·9	2·7
,, ,,	2·3	2·9	2·7
,, ,,	2·3	2·9	2·7
,, ,,	2·4	3·0	3·0
,, ,,	2·4	3·0	3·1
,, ,,	2·4	3·4	3·1
,, ,,	—	3·4	3·2
,, ,,	—	3·6	3·2
,, ,,	—	3·7	3·3
,, ,,	—	3.8	3·3
,, ,,	—	3·9	3·3
,, ,,	—	4·1	3·4
,, ,,	—	4·6	3·4
,, ,,	—	4·6	3·4
,, ,,	—	4·7	3·4
,, ,,	—	4·7	3·5
,, ,,	—	4·7	3·7
,, ,,	—	—	3·7
,, ,,	—	—	3·9

Whilst this paper deals with cheap pig irons there is a big business done in metal of higher price. The foundryman is bombarded with literature describing irons by means of which he may, according to the advertisements, obtain exceptional heat and fluidity, closeness of grain, tightness, machinability, in fact, every desirable property.

Many such irons cost several pounds per ton more than those given in Tables I., II., III. and IV., and most are sold under no real guarantee whatsoever. Let the purchaser demand a signed statement to the effect that the ultimate composition of the iron delivered will be that of the advertised article—not an unreasonable request considering the price—and it is the experience of the Author that the result will be a mass of explanations and excuses but no written guarantee.

TABLE II.

Weight.	200 tons.	
Date.	May 27th, 1918.	
Sample of	% Silicon	% Sulphur
One pig	0·6	·10
another pig	0·8	·10
,, ,,	1·0	·10
,, ,,	1·1	·10
,, ,,	1·1	·10
,, ,,	1·1	·12
,, ,,	1·1	·12
,, ,,	1·2	·13
,, ,,	1·2	·13
,, ,,	1·2	·14
,, ,,	1·2	·14
,, ,,	1·2	·15
,, ,,	1·3	·19
,, ,,	1·5	·21
,, ,,	1·5	·23
,, ,,	1·7	·26
,, ,,	1·8	·26
,, ,,	1·8	·26
,, ,,	1·9	·28
,, ,,	2·0	·31
,, ,,	2·4	·34

Table II. gives typical examples of the variations in the silicon- and sulphur-contents in one consignment of a No. 4 pig iron.

The cheapest grey pig irons are very full of impurities and consequently show the least variation. Tables III., IV. and V. are a tabulation of years of practical work upon many brands of pig iron—phosphoric, hematite and Scotch irons respectively.

TABLE III.

Type of Pig Iron.	ALL CONSIGNMENTS.			Number of pigs sampled.	TOTAL VARIATION.			
	Total Number	Total Period.	Total Weight.		Silicon.	Phosphorus.	Sulphur.	Manganese.
		Years.	Tons.		%	%	%	%
DURHAM and NORTHUMBERLAND								
——No. 3..	8	1913-14	475	25	1·9 to 3·2	1·2 to 1·6	·01 to ·06	0·5 to 0·7
Same	51	1916-20	2282	309	1·6 to 5·0	1·1 to 1·7	·01 to ·13	0·4 to 0·8
As advertised .	—	—	—	—	(2·8)	(1·5)	(·04)	(0·6)
——No. 3..	13	1912-14	465	46	2·1 to 2·9	1·2 to 1·7	·01 to ·06	0·5 to 0·7
Same	50	1915-19	779	165	1·6 to 3·9	1·4 to 1·7	·02 to ·09	0·4 to 0·7
As advertised .	—	—	—	—	(2·6)	(1·4)	(·02)	(0·5)
——No. 3..	7	1911-14	306	28	1·9 to 3·6	1·0 to 1·7	·02 to ·06	0·5 to 1·1
Same .. .	17	1915-19	523	55	2·6 to 4·3	1·0 to 1·5	·01 to ·07	0·6 to 1·3
As advertised ..	—	—	—	—	(2·0-3·0)	(1·1)	(·04)	(0·5)
——No. 4 Foundry ..	8	1918	499	39	2·1 to 3·9	1·4 to 1·6	·02 to ·10	0·5 to 0·8
As advertised ..	—	—	—	—	(1·7-2·5)	(1·1)	(·07)	(0·5)
——No. 4 Forge ..	4	1918	250	31	0·6 to 2·5	0·9 to 1·4	·05 to ·34	0·4 to 1·3
As advertised ..	—	—	—	—	(1·0-1·7)	(1·1)	(·09)	(0·5)
CLEVELAND—								
——No. 3	13	1917-18	297	43	2·3 to 3·7	1·5 to 1·9	·03 to ·08	0·4 to 0·6
As advertised .	—	—	—	—	(2·5-3·0)	(1·5)	(·05)	(0·6)
——No. 3	1	1918	81	18	2·3 to 3·5	1·2 to 1·8	·02 to ·04	0·4 to 0·6
As advertised .	—	—	—	—	(3·0)	(1·5)	(·03)	(0·6)
——No. 3	2	1918	72	15	2·5 to 3.6	1·5 to 1·7	·02 to ·07	0·5 to 0·7
NORTHAMPTONSHIRE—								
——Basic .. .	27	1918-20	415	110	1·1 to 2·6	1·4 to 1·8	·02 to ·13	0·8 to 1·9

TABLE IV.

Type of Pig Iron.	All Consignments.			Number of Pigs sampled.	Total Variation.			
	Total Number.	Total Period.	Total Weight.		Silicon.	Phosphorus	Sulphur.	Manganese.
DURHAM and NORTHUMBERLAND		Years.	Tons.		%	%	%	%
——No. 3	15	1916-19	382	53	1·7 to 4·6	·01 to ·06	·02 to ·09	0·6 to 1·8
As advertised	—	—	—	—	(2·0-2·5)	(·05 max.)	(·06)	(1·1 max.)
—— High Silicon	3	1915-18	35	15	2·6 to 3·8	·02 to ·04	·01 to 03	0·8 to 1·8
As advertised	—	—	—	—	(2·5-3·0)	(·04 max.)	(·03)	(1·2 max.)
—— No. 4	6	1920	83	33	0·7 to 1·5	·03 to ·07	·09 to ·27	0·6 to 1·0
As advertised	—	—	—	—	(about 1·0)	(about ·06)	(·10-·15)	(about 0·7)
——No. 5	7	1919-20	112	44	0·3 to 1.4	·01 to ·07	·11 to ·40	0·3 to 0·9
As advertised	—	—	—	—	(0·7-1·5)	(·06)	(·10-·25)	(about 0·8)
CLEVELAND.								
——High Silicon	22	1920	439	125	1·7 to 4·5	.02 to ·05	·01 to ·11	0·7 to 2·0
As advertised?	—	—	—	—	(3.0-3·5)	(below ·05)	(·01- 05)	(above 1·5)
——No. 1	7	1919-20	200	48	2·5 to 3·8	·02 to ·05	·01 to ·07	0·6 to 1·4
As advertised	—	—	—	—	(3·0-3·5)	(below ·05)	(·01-·05)	(above 1·5)
——No. 3	12	1913-14	199	44	1·4 to 4·5	·01 to ·07	·01 to ·12	0·7 to 2·1
Same	63	1915-20	1332	234	0·8 to 5·3	·01 to ·08	·01 to ·19	0·5 to 1·8
As advertised	—	—	—	—	(2·0-2·5)	(below ·05)	(·01-·05)	(above 1.3)
——No. 4 Forge	9	1913-14	109	30	0·9 to 1·7	·01 to ·07	·07 to ·14	0·8 to 1·4
Same	20	1915-20	438	85	0·7 to 2·4	·02 to ·07	·04 to ·30	0·4 to 1·7
As advertised	—	—	—	—	(1·0-1·5)	(below ·05)	(·10-·15)	(above 1·2)
——No. 3	4	1911-14	39	13	1·7 to 2·4	·02 to ·05	·01 to ·04	0·3 to 1·2
Same	2	1915	25	6	1·7 to 2·7	·02 to ·04	·01 to ·04	0·8 to 1·3

TABLE V.

Type of Pig Iron.	All Consignments.			Number of Pigs Sampled.	Total Variation.			
	Total Number.	Total Period.	Total Weight.		Silicon.	Phosphorus.	Sulphur.	Manganese.
SCOTLAND—		Years.	Tons.		%	%	%	%
——No. 3..	7	1911-14	345	25	2·2 to 3·8	0·4 to 1·0	·01 to ·03	0·9 to 1·6
As advertised ..	—	—	—	—	(2·8)	(0·6)	(·02)	(1·4)
——No. 3..	77	1916-19	972	160	1·8 to 4·8	0·6 to 1·3	·01 to ·11	0·8 to 2·8
As advertised ...	—	—	—	—	(2·3)	(0·7)	(·04)	(1·9)
——No. 3.. .. .	6	1912-14	130	22	1·8 to 3·5	0·5 to 0·9	·01 to ·07	0·5 to 1·6
As advertised .	—	—	—	—	(2·7)	(0·8)	(·03)	(0·8)
——No. 4..	6	1911-12	92	22	1·6 to 3·6	0·6 to 0·8	·02 to ·11	0·5 to 1·2
As advertised ..	—	—	—	—	(2·0)	(0·7)	(·06)	(0·9)

In the above tables the results obtained prior to the war have been separated from those obtained during and since the war—it will be noticed that, so far as actual variation is concerned, the irons are little better or worse in either period. Also below each kind of iron are shown certain figures enclosed in brackets —they are the makers' published compositions.

Very particular attention is called to these three tables. They represent ten years' supervision of the pig irons used in two iron foundries; they cover over 400 consignments of 11,000 tons total weight; they represent 22 different kinds of pig iron; finally they show the results of complete duplicate analyses of more than 1,000 separate pigs. Many other brands have passed through the author's hands but in no instance has he found a pig iron with a constant ultimate composition, with an ultimate composition as advertised or with an ultimate average composition which one could predict before analysing. Total Carbons are not shown in above tables, although hundreds upon hundreds of estimations have been made; it is impossible at present to say what is the average content of carbon in any particular kind of ordinary pig iron.

Too much stress cannot be laid upon the deductions to be drawn from the above tables. Once and for all can the engineer cast overboard all faith in rule-of-thumb mixtures made from pig irons of constantly varying composition. Pig iron of standard ultimate composition would solve nearly all the difficulties of the jobbing foundry and most of those of the foundries doing more important castings—which remark applies equally to all branches of engineering and to all types of castings.

It is unfortunately necessary to point out that troubles do not always cease upon the cessation of rule-of-thumb methods as everything depends upon whether they have been discarded for better ones and, as will be shown later, this is seldom the case.

Nevertheless, castings of nearly standard composition can be produced even under the dubious conditions of cupola control to which, for lack of measuring instruments, we are still subjected. As a practical and typical instance may be quoted some important turbine castings, made earlier this year, of which the metal was required to give 11 tons tensile and 2,500 lbs. transverse strength—the testbars being cast on the castings and verified in the usual way. This series of castings is given in Table VI., and it is interesting to note that no pig iron as expensive as Scotch iron was used and that owing to one or two of the constituents running short the mixture was changed from time to time.

TABLE VI.

CASTING.		STRENGTH.		CARBON.			OTHER ELEMENTS.			
Date.	Weight.	Tensile.[1]	Transverse.[2]	Combined	Free.	Total.	Sil.	Phos.	Sulph.	Mang.
	tons	tons sq."	lbs.	%	%	%	%	%	%	%
May 7th.	17	11·5 (flaws)	2739 (flaws)	0·78	2·61	3·39	1·67	0·63	·064	0·85
15th.	11½	14·0	2958	0·78	2·54	3·32	1·75	0·68	·069	0·88
22nd.	11	12·5	2799	0·79	2·58	3·37	1·75	0·60	·057	0·91
Aug. 11th.	4½	11·6 (flaws)	3116	0·73	2·66	3·39	1·69	0·54	·067	0·83
23rd.	13	13·8	2779	0·82	2·51	3·33	1·74	0·51	·066	0·95
Sept. 6th.	12½	13·0	2938	0·76	2·59	3·35	1·68	0·56	·077	0·82

1. Bars cast 1in. diameter and machined to 0·798in. diameter.
2. Bars cast 1⅛in. square, machined to 1in. square, and tested between supports 12in. apart.

The above figures, being obtained from testbars attached to the castings themselves, prove that much can be done to standardise cast iron even in large work and even with our present lack of knowledge. Very few foundries do this and equally few engineers appear to have grasped the importance of being able to do it. Progress is well-nigh impossible so long as no two castings are alike in composition—the situation may be expressed, in popular language, as one where we never know where we are. Unusual failures or successes arise out of departures from the normal state and in order to study the properties of any one type of cast iron, and there are hundreds of types, we must be able to reproduce it at will, time and time again. So far as the author has obtained samples he has found no foundry turning out standard cast iron castings for marine work or for any other work.

Undoubtedly the first step towards the understanding of cast iron is the control of its composition under ordinary foundry conditions. Some firms are establishing the method of superheating the cupola-melted metal in an electric furnace, while others, mainly abroad, use an open-hearth air furnace. Good as these methods may be they do not in any way alter the fact that if the cupola-melted metal is out of control any subsequent treatment of it is merely patching up a bad job. If the cupola is to be used at all then the production of cupola-melted metal to any required composition is essential. The turbine castings shown in the last table are merely given as examples of controlled compositions as compared with the opposite of controlled compositions as shown later on under the subject of castings for Diesel engines (Tables VIII. and IX.) This control of composition is merely a matter of experience and knowledge and the day will come when we shall be able to specify our cast iron exactly as we do now with our steel, and that without the help of any other furnace than the cupola.

*In connection with the use of an electric or other furnace in conjunction with a cupola there are several important points to keep in mind. Firstly comes the fact that what we know about cupola practice is insufficient to enable us to predict that what we require cannot be obtained from a cupola. It is a wonderful furnace and very little reliable work has been done upon it, far too little to justify us in discarding its use or in rushing into anything involving higher costs of production. Secondly, castings have to be produced at prices which will compete with those of the foreigner; electric power is not cheap in this country and the upkeep of electric furnaces is no small matter. Lastly, it is not to be immediately assumed that the more carbon, phosphorus and sulphur we abstract from the iron the better will be the metal for the purposes of making castings. Empirical or rule-of-thumb methods and reasoning have thus

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* Paper to be read in connection with The Institute of British Foundrymen in our Lecture Hall, on March 9th, on this subject.

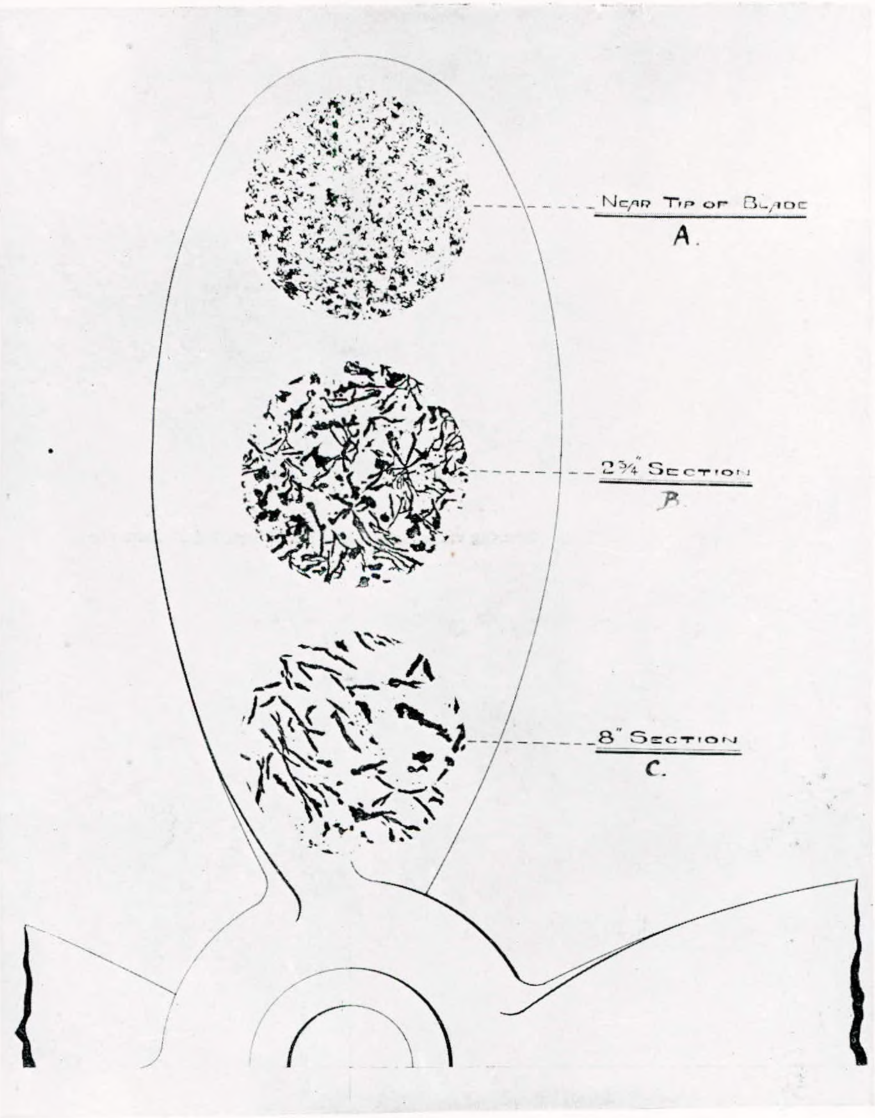

Fig. 1.

Propeller. Showing variation of Graphite according to position. Magnified 12 diameters.

the stresses produced by the edge of the cutting tool; for the same reason also has it little or no elongation and many other properties peculiar to itself.

A practical object lesson of the truth of these things is obtained from a large propeller casting, blades and boss complete, and weighing, say, eleven or more tons. Here the great mass of the boss causes extremely slow cooling of the adjacent parts, the effect getting less and less along the blades away from the boss and also the section of the blades themselves gets less. In practice, the molten metal flowing to the tips of the blades is almost chilled and, therefore, the tips are very hard and brittle and contain but little free carbon. A short distance from the tip, this cooling is less severe and more carbon is released, with the consequence that the metal is grey but rather hard—the metal being as seen at "A" in Fig 1.

Half-way up the blade the section is greater and the heat given off by the cooling of the boss delays the cooling, hence the metal will be very normal and perfectly grey and machinable—as shown at "B." At the root of the blade, where it joins the boss, the cooling will be extremely slow, taking some hours probably, and therefore the iron has time to free itself amost entirely from combined carbon and when cold is found to be full of large graphite—seen at "C."

Thus does a propeller casting demonstrate the fact that the quantity and size of the graphite is greatly ruled by the rate of cooling of the metal from hot solid to cold solid. It shows how impossible it is to expect the test bar to represent the casting, also if the testbar be cut out of the casting itself the result will be representative only of that part of the casting from which it was cut.

Another practical example may be obtained from what the foundryman calls a "burn." When a casting is slightly defective it is sometimes possible to "burn" on a new piece by running molten metal over the defective part until the surface of the original casting begins to get molten when the stream is checked and the metal allowed to solidify. A "burn" is similar to a weld. Fig. 2 shows the graphite in a section of the metal taken at right angles to the "burn," where the same effects are observed as in the case of the propeller—the casting itself having large graphite and the "burnt-on" metal, owing to rapid chilling, having very small graphite and very little of it. Of course, the metal will be much harder and less machinable. An interesting study is presented by the combined carbon and general structure of the "burn" as seen in Fig. 3, the fir-tree growth of long crystals being particularly noticeable and enlightening.

From these things it should be easily understood that the quantity, formation, size and distribution of the free carbon or graphite have enormous effects upon the properties of the metal. The photographs shown in Figs. 4, 5 and 6 give an idea of some different kinds and formations of graphite; considering the large number of flakes there is to the cubic inch of cast iron it is not surprising that the question of graphite is an important one, though little is known about it up to the present.

The matrix of iron, in which the graphite occurs, contains the remainder of the carbon combined with it and, under the microscope, this carbide is seen in thin layers or laminations having a characteristic appearance by reason of which it has been christened "pearlite." However, should there be more than a certain quantity of combined carbon, namely, more than is required to form the greatest possible amount of these pearly layers, then the excess forms more definite and relatively thicker lamellæ, called "cementite"—which make up a kind of net-work structure throughout the material, dividing it, so to speak, into grains.

It was demonstrated above, by means of the propeller casting, that the graphite plates were larger in the slower cooled parts of the casting than in those cooling relatively quicker, so also does the same appear to apply to the "pearlite" or combined carbon. An example of this may be got from the following case of a cylinder liner with testbars cast on.

The particular liner mentioned here was about 3¼ tons weight including the "head." From this "head," which was about 4½in. thick, a testbar was cut and compared with the testbar cast in shape on the casting.

Consequently we are about to compare the same iron from the same casting to see what differences have been caused by a casting-thickness of 4½in. and one of 1in. (namely, the testbar cut out of the head and the testbar cast on the casting)—both bars were machined to 0·798 inches diameter. Figs. 7 and 8 respectively show the graphite and the pearlite in the testbar *cast on the casting*, while Figs. 9 and 10 show the same things in the testbar *cut out of the casting*. It will be seen that the graphite and pearlite in the former are small in size compared with those of the latter, the massive pearlite being particularly remarkable.

This cylinder liner metal is of interest because it has had some little success in actual service. Under superheat conditions, and even under ordinary conditions, ordinary liner metal leaves much to be desired, and the metal shown above was evolved gradually over a number of years of observation of the behaviour of various kinds of cast iron. Heavy and thick as are these castings the testbars cut out of them give nearly the same tests as the testbars cast on them, namely, about 12 tons tensile and 2,300 lbs. transverse (on Admiralty square bar).

The metal has a low Brinell number in the neighbourhood of 212 or less, but cannot be cut with a hacksaw. It can be machined commercially in the shops at the rate of 45ft. per minute with a depth of cut of $\frac{1}{4}$in. by 1/32nd inch feed per revolution.

After machining a good surface is left which develops under service conditions and exhibits the desired wearing properties.

Practical men know only too well the metal they describe as "hard" iron—metal possessing every undesirable property, including weakness and brittleness. It is a matter of engineering interest, therefore, to know that it is possible to make a tough and strong iron which has the correct "wearing hardness," and which has proved its suitability for cylinder liners, valve liners, piston rings and so on, under superheat conditions.

The "hard" iron, the *bête noire* of foundries and of engineers, is a product of ignorance or of misfortune—it is referred to later.

Phosphorus in cast iron is the element without which most foundries would close down through inability to run castings with cupola-melted metal. The phosphates solidify later than the mass of the metal and consequently form segregations in between the iron crystals—particularly in large castings where the cooling is slow.

Fig. 11 depicts one of these phosphide segregations as a lake of brittle material separating several iron crystals. At a lower magnification in Fig. 12 may be seen how these "lakes" occur throughout the mass; while under other conditions may be seen the absence or presence of a net-work structure (Figs. 13 and 14)—but that point is dealt with further on.

The phosphorus-content may be kept as low as is found compatible with good foundry results, in heavy work about 0·4% or 0·5%.

Fig. 4.
Pig Iron. Shewing Graphite. Magnified 50 diameters.

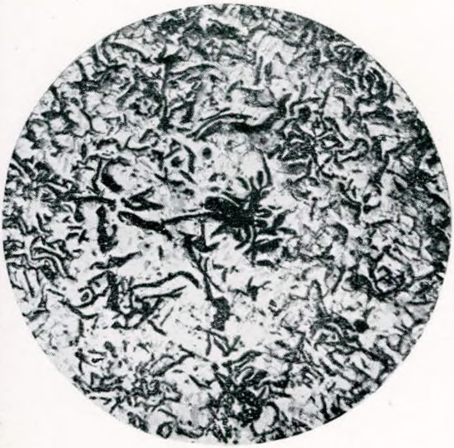

Fig. 5.
Cast Iron. Shewing one type of Graphite.
Magnified 50 diameters,

Fig. 6.
Cast Iron. Shewing another type of Graphite.
Magnified 50 diameters.

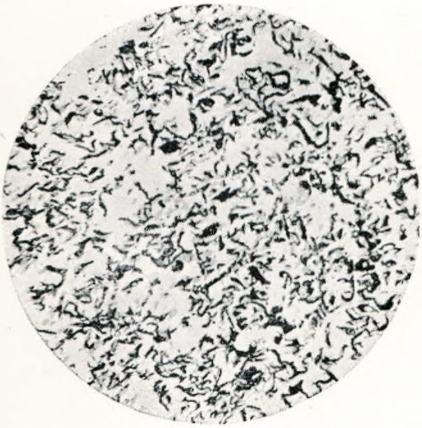

Fig. 7.
Testbar cast on Liner. Shewing Graphite.
Magnified 25 diameters.

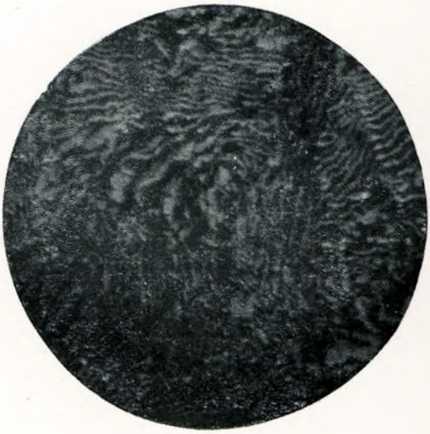

Fig. 8.
Testbar cast on Liner. Shewing Pearlite.
Magnified 1,100 diameters.

Fig. 9.
Testbar cut out of Liner. Shewing Graphite.
Magnified 25 diameters.

Fig. 10.
Testbar cut out of Liner. Shewing Pearlite.
Magnified 1,100 diameters

In less important or lighter pieces the phosphorus is well kept below 1%, while it should rarely go above 1·3% in any casting. The rule-of-thumb foundryman is fond of high phosphorus because the engineer likes a good-looking casting, but when the engineer learns to judge other than by the appearance it will be necessary to keep the phosphorus down to some such limits as those suggested above.

In certain compositions the phosphide appears to be expelled from the grains of the metal and to assemble around those grains in a net-work similar to, but not the same as, that assumed by the cementite mentioned above. In weak or poor irons this phosphide is retained more or less within the grains of the metal as seen in Fig. 13, but in a strong iron, perhaps of very similar composition (with the exception of one of two elements) the phosphide is expelled and forms the net work shown in Fig. 14. The future understanding of the true causes and effects of this rejection or retenton of the phosphide would seem to be a more important matter than has hitherto been anticipated.

Irons in which the sulphur-content is not more than balanced by the manganese-content are relatively weak and hard and possess poor foundry properties as compared with irons similar in composition other than that the sulphur is properly balanced. Curiously enough it would appear as if the test of net-work or no net-work (Figs. 13 and 14) of the phosphide may be one means of discovering whether the sulphur-manganese balance is swinging in favour of the manganese.

From a tabulation of some thousands of results obtained in actual practice the author has found no exception to the rule that the weak or faulty member of two irons of very similar composition is that one where the sulphur-content is inadequately balanced by the manganese-content. From thousands of practical results it is comparatively easy to select a few of very similar composition, save in the sulphur-manganese balance, and to show the effect mentioned above. Table VII. gives a typical selection of bars with varying sulphur-content and affected only by the amount of manganese balancing the sulphur.

TABLE VII.

Tranverse Strength.[1]	Carbon.	Silicon.	Phosphorus.	Sulphur.	Manganese.
lbs.	%	%	%	%	%
2342	3·43	1·17	0·60	·231	0·23
3533	3·47	1·27	0·61	·220	0·41
2025	3·39	1·67	1·12	·176	0·27
3494	3·40	1·64	1·08	·172	0 49
2352	3·37	1·56	1.21	·137	0·28
3553	3·35	1·52	1·15	·132	0·44
1747	3·45	1·65	1·08	·122	0·27
3791	3·41	1·62	1·05	·129	0·51
2223	3·40	1·72	1·15	·110	0·25
3672	3·38	1·73	1·14	·112	0·58
3732	3·37	1·73	1.01	·116	0·40

[1] American "arbitration" bar, 1¼in. diameter, tested between supports 12in. apart.

It is to be most clearly understood that the above examples are extremes and that the nearer one gets to the critical point of equilibrium the more difficult does it become, by chemical analysis, to detect any difference between the two irons—but the physical properties remain either very good or very bad right up to each side of the equilibrium.

It is possible, even probable, that sulphur and manganese together are the most vital combination of elements in cast iron.

Silicon control has assisted ironfounders the world over, but sometimes it fails, and the failure is usually attributed, by the foundryman, to high sulphur. Overwhelming prejudice has prevented anyone from experimenting practically with high-sulphur metal, but hundreds of tests in ordinary practice have proved to the author that good irons can be made with as much or more sulphur that is contained by other irons said to be poor by reason of their sulphur—the real difference being that the good iron has enough manganese to completely balance the sulphur whereas the poor iron has not. The author hopes to pursue this point in another place as it is of the highest importance that this phenomenon should be thoroughly ventilated and made use of in the future.

Foundries have ever been prone to sudden mysterious spasms of bad metal or bad castings, coming and going as secretly as a disease, and although the management often takes credit for getting away from the trouble it can seldom give any definite

Fig. 11.

Phosphide " lake " separating crystals. Magnified 250 diameters.

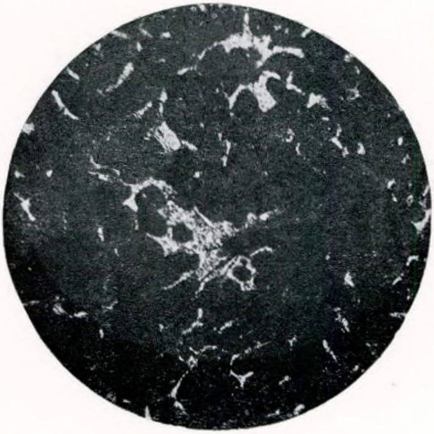

Fig. 12.

Formation of Phosphide " lakes " in Cast iron
Magnified 25 diameters.

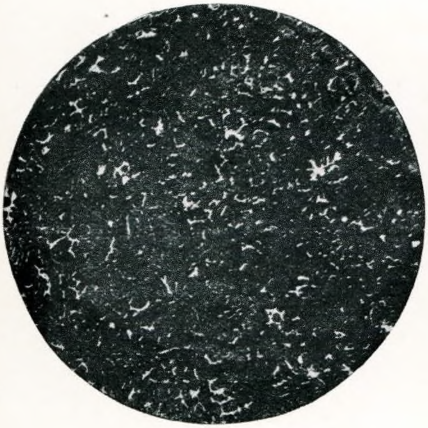

Fig. 13.
Bad Phosphide Network in Cast Iron
Magnified 25 diameters,

Fig. 14.
Good Phosphide Network in Cast Iron.
Magnified 25 diameters.

Fig. 15.
Sulphur Print of Cast Iron.
Magnified 4 diameters.

Fig. 16.
Sulphide "Globules" in Cast Iron.
Magnified 100 diameters,

explanation of what it has done. In every such case in the author's experience the iron has always suffered from inadequately-balanced sulphur and, what is most important, there has never been any other tangible evidence of the reason for the trouble than that afforded by this wrongly balanced sulphur. The author is well aware that other theories exist and are warmly upheld by their exponents, but he offers these practical results and observations as something better to work on, something impersonal and more scientific, than the many disconcerting theories now existing upon little more evidence than the fact that two irons (of similar composition) are found to give different physical tests and somebody comes up and says "therefore it must be the pig iron, or the oxygen" but offers no convincing proofs, indeed, usually offers no proofs at all.

For the moment, therefore, we may take it that there does exist a very vital equilibrium point between the sulphur and the manganese and that this point must be taken into consideration before we can accept any other explanation of the difference between two irons, one on one side of this point and the other on the other side.

Silicon-control is often too weak and the testbar is liable to have superior properties and composition to the casting it represents. Moreover, it is sometimes impossible to alter the silicon percentage for fear of harming other properties essential to the making of a good casting. With sulphur-control, low sulphur for one type of work and higher sulphur for another, these difficulties can be got over and the condition and amount and disposition of the carbon and of the eutectics can be controlled in the casting itself—the *sine qua non* being that no matter what the quantity of sulphur that of the manganese must be more than sufficient to balance it.

The occurrence of the sulphides in cast iron is extremely interesting. Fig. 15 is a sulphur print (magnified about four diameters) of these sulphides. Fig. 16 shows them as tiny "globules" (in half-tone in the picture) but it is to be remembered that the magnification is 100 diameters and that the "globules" are infinitely small in the iron itself. Fig 17 illustrates these same "globules" photographed at 1,600 diameters. The beautiful view of cast iron, revealed in this last photograph, is a matter for discussion before a metallurgical society rather than here, but it may bring to mind some conception of the great and unexplored regions of the world of cast iron and the urgent necessity for scientific control and investigation.

Turning to internal combustion and to all high temperature engines, the problem of grey iron castings is to make them stand up to the work without alteration of strength, form or surface; to be able to make them alike time and time again; to make them from the cupola alone if possible; and finally to make them of such weights and at such prices as will enable our engines to compete in all markets. To-day we are far from any such ideal and barely beginning to aim at it.

When cast iron is drastically heated and cooled several times it begins to "grow" and the graphite enlarges as shown in Figs. 18 and 19. Assuming that the highest temperature attained by any part of an internal combustion engine is in the neighbourhood of 550° C. (1020° F.) we are up against the problem of producing some type of cast iron which will not suffer from insidious deterioration. It would not seem to be a difficult matter to produce such metal, nor would it be save for the fact that foundry work and cast iron generally has been for so many years a "mystery" controlled by supposed secrets known only to a few, that at the moment we are faced with the problem of having little or no precedent, data or literature of any value in practical work. Hundreds of instances are known where foundries have positively refused to attempt to produce the particular quality of metal asked for—the author knows of five foundries which "turned down" the idea of making an iron which the author makes regularly, they said it could not be done and was not practicable and this, probably, because it upset their traditions, or would have done so if they had made it successfully.

To a very great extent the engineer has allowed himself to be at the mercy of people who, because they themselves had not done a particular thing or had failed to do it said that therefore it was impossible; frequently their strongest argument is that it is "not practical," which conveys a hidden imputation to the effect that the man suggesting it does not know what he is talking about, or that he lives in a much less important and easier sphere than the other man.

As a matter of fact the ignorance existing to-day is remarkable. Large firms are turning out castings which are hardly twice alike as regards quality of metal, and naturally it is impossible for such firms or their clients to make progress or even obtain knowledge as to what they are doing. Specifications relating to cast iron are mere rhetoric, they abound with such phrases as "tough close-grained cast iron of good quality," and

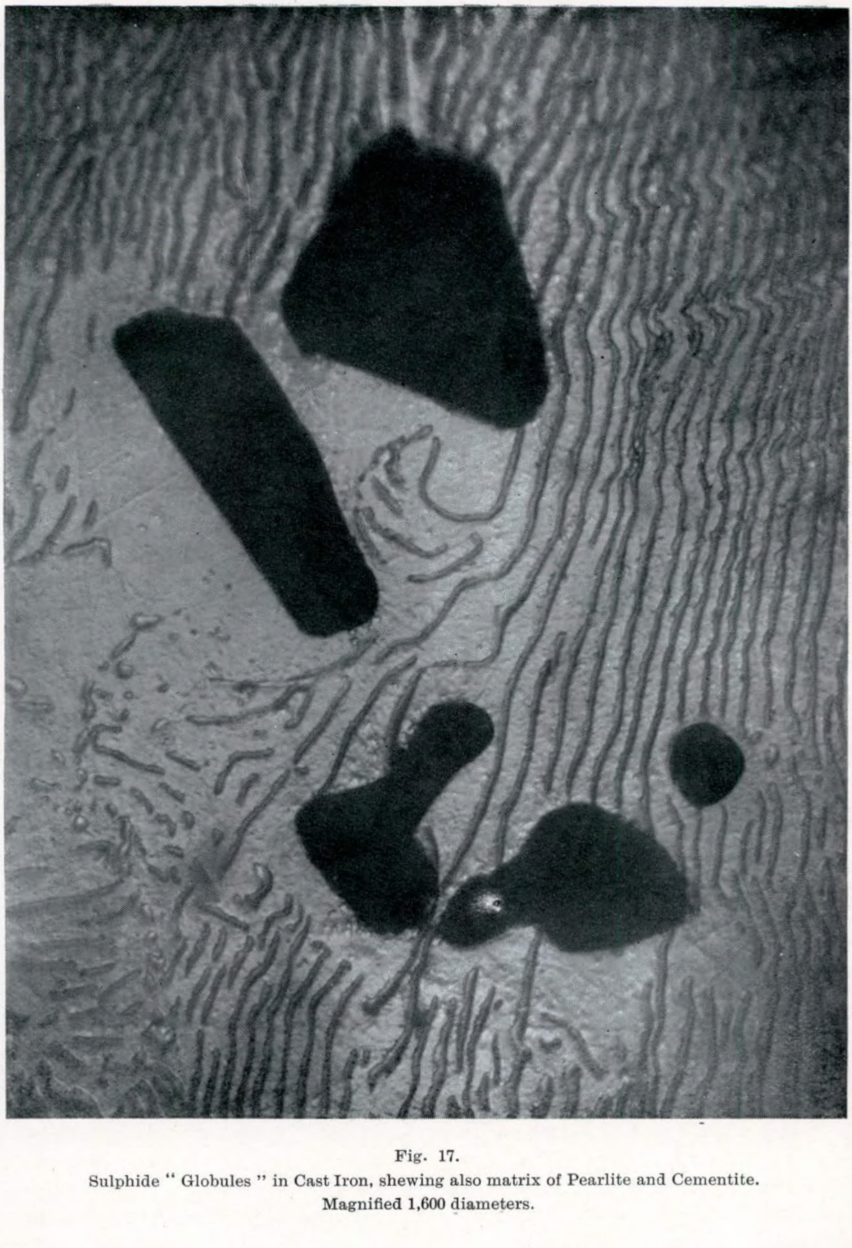

Fig. 17.
Sulphide " Globules " in Cast Iron, shewing also matrix of Pearlite and Cementite.
Magnified 1,600 diameters.

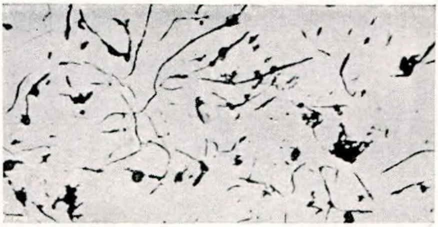

Fig. 18.
Graphite in Cast Iron before growth.
Magnified 100 diameters.

Fig. 19.
Graphite in same Cast Iron after growth.
Magnified 100 diameters.

since nobody knows what is iron of that quality and nobody can test for it then, if the castings look all right, everybody is satisfied. This will be disputed, but before entering into any discussion it would be as well to turn to the large propeller casting mentioned earlier in this paper and consider whether the "tough close-grained iron of good quality" is in the tips of the blades, half-way up or in the boss, and apply the same reasoning to every casting containing more than one thickness of metal.

Also we hear of "hard" iron or "soft" iron, and the failure of this or that casting is attributed to the one or the other, irrespective of all knowledge whatsoever and apparently entirely unaware of the fact that extremely good or extremely bad iron may come under either the class termed "hard" or that termed "soft." For instance, if you put "hard" unbalanced-sulphur iron into an important and intricate casting then that casting will be extremely likely to fail, possibly a few minutes after the metal enters the mould, and in any case the metal will be poor and brittle and have bad machining properties. On the other hand, the same "hard" iron with the sulphur properly balanced would be extremely likely to give the desired qualities of hardness and toughness and to cast well in the foundry.

The author has been able to survey several specimens of cast iron made by well-known makers of internal combustion engines, and in no case had the castings a standard composition nor had they an average standard composition. Also it may be clearly stated that no particular attempt at producing anything other than ordinary machinery iron could be detected.

Table VIII. shows some of the irons from one engine, and it does not take a metallurgist to see that no two are alike, that the names "cylinder" or "liner" or "piston" are mere names and point to no particular quality of metal, indeed, the liner metal is sometimes of cylinder quality and, at other times, the cylinder metal is of liner quality, while the piston metal fluctuates in between.

TABLE VIII.

Description.	Silicon.	Other Elements.
	%	
Cylinder .	1·42	Combined Carbon varies between 0·26 and 0·59 %.
Another ..	1·54	Free Carbon ,, ,, 2·74 and 3·22 %.
Another ..	1·56	Total Carbon ,, ,, 3·29 and 3·54 %.
Another ..	1·59	Phosphorus ,, ,, 0·26 and 0·61 %.
Another ..	1·79	Sulphur ,, ,, 0·083 and 0·113 %.
Another ..	1·85	Manganese ,, ,, 0·50 and 0·66 %.
Another ..	2·11	Transverse Strength ,, ,, 2,480 and 3,140 lbs.
Another ..	2·12	Tensile Strength ,, ,, 8·9 and 13·5 tons.
Liner ..	1·03	Combined Carbon varies between 0·56 and 0·80 %.
Another ..	1·55	Free Carbon ,, ,, 2·61 and 2·95 %.
Another ..	1·59	Total Carbon ,, ,, 3·30 and 3·58 %.
Another .	1·64	Phosphorus ,, ,, 0·30 and 0·61 %.
Another ..	1·71	Sulphur ,, ,, 0·077 and 0·100 %.
Another ..	1·75	Manganese ,, ,, 0·53 and 0·90 %.
Another ..	1·76	Transverse Strength ,, ,, 2,280 and 3,024 lbs.
Another ..	2·16	Tensile Strength ,, ,, 10·2 and 14·9 tons.
Piston .	1·35	Combined Carbon varies between 0·60 and 0·72 %.
Another ..	1.57	Free Carbon ,, ,, 2·69 and 2·75 %.
Another ..	2·12	Total Carbon ,, ,, 3·38 and 3·41 %.
		Phosphorus ,, ,, 0·30 and 0·61 %.
		Sulphur ,, ,, 0·078 and 0·097 %.
		Manganese ,, ,, 0·64 and 0·81 %.
		Transverse Strength ,, ,, 2,480 and 3,140 lbs.
		Tensile Strength ,, ,, 12·1 and 14·4 tons.

All the above are supposed to represent the highest possible class of special material for special purposes—in reality they are similar to ordinary rule-of-thumb products.

In Table IX. are given the compositions of the "special" iron from another equally well-known maker of internal combustion engines, and once again is the material of a nondescript and varying character.

TABLE IX.

Description.	Silicon.	Other Elements.
	%	
Cylinder	1·00	Combined Carbon varies between 0·85 and 1·06 %
Another	1·21	Free Carbon .. , 2·18 and 2·55 %
Another	1·30	Total Carbon .. ., 3·24 and 3·40 %
Another	1·43	Phosphorus .. .. 0·67 and 1·06 %
—	—	Sulphur ., ., 0·059 and 0·100 %
		Manganese .. .. 0·60 and 1·28 %

Therefore these people have not only made no advance in the quality of their material but they have not as yet succeeded in controlling their work so as to produce any one quality more than once. The expense of electric furnaces and so forth is not justified so long as we are willing to accept materials such as the above.

The other day a man came to the author offering high-priced low-carbon pig iron "specially suitable for Diesel work." After looking at his iron and the composition of it the author asked him: "Why is this material specially suitable for Diesel work?" The man was quite at a loss and possessed not one fact or figure upon which to base his claim, and in after conversation he assured the author that his iron was selling extremely well and that never before had he been asked why it was specially suitable for Diesel work and that, moreover, he did not know.

In order to be able to raise the working temperatures and pressures of our engines or to lighten their structures it will be necessary to know more about cast iron than we know to-day. The chemist himself knows very little about it, but he is in a good position to find out. If this country can get a number of chemists working upon these lines in different works then the volume of information will become greater and wider and progress will become apparent.

The foundryman has, as a whole, already accepted the chemist, a fact very greatly to his credit. The engineer, however, has got to do more than accept the chemist, for he will, in the future, need to accept a certain amount of chemistry. Our big educational institutions, many of them training young engineers, teach little or nothing about cast iron and the metals of commercial engineering, the result being that these young men go into the works or into the drawing offices of the works without any mental picture or any conception whatsoever of the behaviour and constitution of metals. The foundrymen, many of whom are eager to learn, have nowhere to go to get knowledge or at any rate knowledge of the type that they can assimilate and that will be valuable to them.

The whole system needs overhauling, and the engineer is the only one powerful enough to bring about that overhaul—let him demand more instruction and more knowledge and the supply will speedily be to hand. Then there is the case of the cast Iron Research Association, which needs to be given a fair sporting chance of proving its worth; it would appear to be obvious that everybody making, buying, selling or using castings has got a stake in this Association and should look after it on the chance of getting value out of it—as a matter of fact there is no "chance" but a certainty *providing the Association receives proper support*.

In presenting this survey of practical work and of observations made under works conditions, the author has aimed at one thing only, namely, to arouse interest in that most fascinating and useful of metals, cast iron, and in its great possibilities.

This paper is the outcome of a conversation between your esteemed secretary, Mr. Adamson, and Mr. Summers Hunter, of the North Eastern Marine Engineering Company.

In expressing his thanks to these gentlemen for the facilities that have been so freely given, the author wishes also to include the members of this Institution as a whole.

The photomicrographs, lantern slides, etc., were produced by Mr. C. Gresty, the author's head assistant.

DISCUSSION.

Mr. W. McLaren: The lecturer has referred to the education of the young engineer. But if we were going to have mass production—I have no cause to quarrel with this—yet under the conditions that pertain to mass production, where are we going to get the trained engineers? If the firm that the youngster serves has not a foundry, or if he has to get so many hours of educational work for one, two or three days a week, he has not the chance to see what is going on in the foundry. In the olden days the boy had the opportunity of getting a look at the foundry when he took patterns there. It did not seem a happy change when we were breaking into the old system of practical apprenticeship with the probationary period now allowed for classes,—which we had the opportunity to take on our own initiative. It would be worth while to go back to it again, and to let the boy be educated after he had done his eight hours day. It used to be a ten hours day (6 a.m. to 6 p.m.) and the question is, are we producing any better or healthier men now than were brought up in those days? I think not, though they may be more scientific *perhaps*. It stands to reason that we must have mechanics, and we must have trained heads. In other words, if we specialise we must put some restriction on what one is going to learn from say fourteen to sixteen years of age. I have pleasure in thanking the author for his valuable lecture, and propose that some other night should be set aside for its discussion.

The **Hon. Secretary**: I am quite sure that those of us who know Mr. Summers Hunter will endorse the remarks of Mr. Young. I have a letter from Mr. Hunter, who regrets that he is not with us to-night. Having met him at the Exhibition we discussed several points, and one result is that Mr. Young is with us to-night to give this excellent paper on which Mr. Hunter comments as follows:—"I think it will be interesting and educative. It really represents what we have gone through in developing the scientific control of our industries during the the last 10 years, and I think you will notice in the paper here and there, evidences of where the practical side of our work comes in, and harmonises with one of the most important and scientific operations in connection with the designing and building of marine engines. Looking back over 50 years experience of engineering I am sure that the question of dealing with metals has been an outstanding problem, pressed upon one with more or less insistence from time to time, and in this way to every engineer recent developments have been of increasing interest, but unfortunately we did not all get opportunities of taking part in these developments; and here let me say that there is no more welcome visitor to our laboratory than the superintending or consulting engineers. It is surprising the increasing number of enquiries we get from such visitors, and Mr. Young and his staff are only too glad to reply to enquiries as far as possible, and give our friends the full benefit of any information we have. I am only one of those who during the last few years have noticed the increasing interest taken in our foundry problems, by those who are directly responsible to shipowners for the construction and running of marine engines of all types, and particularly the latest types dealing with higher pressures and temperatures. It is a subject of great interest, and I much regret that I am unable to be with you and take part in what I know will be a most interesting discussion, and perhaps in some respects an epoch-making one."

I may add in reference to Mr. Maclaren's suggestion, that next Tuesday, on account of the postponement of an expected paper, we have a free evening, or we could arrange for an evening in January.

Mr. J. H. **Anderson**: Our thanks are due to Mr. Young for the very capable and scientific lecture he has given. It has been quite an eye-opener for those who knew but very little about the manufacture of cast iron. I think we cannot quite agree with some of the points indicated. Engineers, for instance, do not like to consider that they cannot go into fine measures; as an example, Mr. Young would find that some of the instruments used were made by engineers. With engineers, accuracy does not mean so much the measuring of very small things, as the measuring of large things with absolute accuracy. It is well known that the accuracy of watchmaking is not near to the accuracy, comparatively speaking, of even ordinary engineering. Engineers have to use a factor of safety, and if the chemist, with a little more co-operation with the engineer, can give us standard cast iron, as has been suggested, engineers would be pleased to lower the factor of safety. To give an illustration dealing with ferro-concrete, where very fine calculations had to be made to get an economical beam. A factor of safety of five to eight or more might be given, but when the work was put out the factor of safety was upset by the workmen displacing the steel with their shovels. In the case of the propeller, if we could get a standard metal, what would be the relation between the finished casting and the metal? Is it not mainly a question of temperature control or not controlled, between the thin metal at the top of the blade and the thick metal towards the boss. The lecturer may probably agree that it is absolutely impossible to get a standard fuel to give uniform temperature unless something is used like electricity. Therefore if we cannot get a standard fuel the various results of the cupola packing will be different, and consequently the admission or control of the air to the cupola will be impossible to regulate because of the variable coking quality and choking effect of this fuel. I would support the proposal for an adjourned discussion.

Mr. Young: It is evident that some of my terms have been misunderstood. I do not mean to imply that the engineer does not appreciate the term accuracy as used by an engineer or a watchmaker, but that he did not appreciate the term as used by a chemist. With regard to controlling the temperature of the propeller when this is being cast, how could this be done so as to get every section alike? With its blades and boss it has many different sections, and the rates of cooling in the casting depend upon the position and thickness of the various parts. It is a much bigger matter than to say that all you have to do is to control the temperature. The object is to make the metal such that it is not affected by temperature so much. With regard to the question about cupolas. The difficulty about cupolas is not one of fuel even though it were standardised; but the great difficulty is that the cupola in the furnace is worked by a blast, and in order to control that furnace one had to know the volume of the blast that was going on. Not pressure, but volume. I do not believe that anything has been brought out which would measure the blast going into a cupola.

The CHAIRMAN: Discussion adds greatly to the value of any paper delivered in a scientific institution, and there are quite a number of points one would have liked to have put before Mr. Young, for reply, but time has prevented. The question that bothered engineers was not so much the composition of the cast iron, but what they should aim at, and how they were to deal with it. For instance, in the question of welding cast iron, in many cases it would save an enormous loss if this could be satisfactorily and reliably done. In some cases it was done satisfactorily; but in others, for no apparent reason, there was no result or the welding was not reliable. In some of the tests shown on the screen, results had been given which he could not quite follow.

Mr. YOUNG: These points and possibly others should be brought up at a subsequent discussion, after members had an opportunity of reading the paper, and I shall be pleased to elaborate.

The CHAIRMAN: Another matter which has been brought up is the Brinnell test. That has always been recognised as very reliable for steel as showing the tensile strength, whereas I do not know, from what Mr. Young has said, whether he wanted to bring out the test as showing the tensile strength of iron, or the good it serves. He also mentioned about the spontanoeus cracking of cast iron. That is a thing that engineers are up against at times. Castings crack after they have been cast, in some cases not for weeks, due it was believed to the section not being properly and uniformly carried out in the design. But is there anything more? That is what we want to get at. Then there is the growth of cast iron, due to repeated heatings and coolings. What kind of iron does the lecturer suggest should be used to overcome this trouble? The paper is bristling with such questions, and I am sorry that the discussion has not included such points, but in his further reply, perhaps Mr. Young would give a little information on these points.

Mr. Young: In regard to questions on the growth of cast iron, burning, and such matters, it would need a metallurgical lecturer to deal with those points. As to my lecture this evening, it has attained its object if I have made engineers see that there is something necessary which has not been included in their own profession. The chemist in the works can save a good deal of money to the firm, and make progress where no progress had been made before. If the chemist is given the responsibility for his own work, later on we shall produce a race of engineering chemists who would be of great value in engineering. There are several great works where they have established a chemist on these lines.

Mr. Watson: I propose a vote of thanks to Mr. Young for his very interesting lecture. Engineers ought to take up the study of metallurgy; there is no doubt more metallurgy ought to be taught to engineers in our schools and colleges.

Mr. W. Maclaren: I have pleasure in seconding the vote of thanks. The engineer is quite willing to combine with the chemist in engineering matters, and looks to receive a great deal of assistance by so doing. I know of works where the chemist and the engineer are on the best of terms, and try to help one another. It is certainly a case for the chemist to step in and offer his services, and I do not think any engineer would shut the chemist out. That fact has been proclaimed in the Institute before this evening. While seconding this vote of thanks, I would like to remark that thirty years ago a member of the Institute in his foundry could produce a casting with a tensile strength of 14 tons to the square inch. It was a certain wheel for a mill drive. The foundryman who did this was a member of the Institute, and I remember going to the foundry. I do not know what the foundryman's science or secret was, but that was the metal that was produced; and I believe our Hon. Secretary knows something about the castings produced in the shop referred to, from his own experience of their productions.

Mr. Young: I thank you for your reception. There is one point I want to emphasise, that there is no antagonism whatever between the chemist and the engineer. I am present by the courtesy of engineers; my employers are engineers, and my presence and reception here this evening indicates the reverse of antagonism. Engineers and chemists should work together.

The discussion was ultimately adjourned till January 24th, 1922, when it was arranged that members of the Institution of

British Foundrymen—who are welcome to all our meetings—should receive special invitation, through Mr. V. C. Faulker, Hon. Secretary, London Branch, who was present to-night.

CONTRIBUTED BY CORRESPONDENCE.

Mr. E. ADAMSON (18, York Street, Sheffield): Mr. Young is to be congratulated on the exhaustive way in which he has treated the subject of the problem of grey iron castings, and for some of the interesting facts he has put on record. Not the least interesting are the micro-sections taken from the blade of a propeller, showing the influence of slow cooling on crystalisation, and it is perhaps the first time the micrograph of a "burn" or weld in cast iron has been shown. What would add to the value of these photographs would be the total carbon, graphite and combined carbon of each of the sections shown by the micrographs.

His statement that the quantity, formation and size and distribution of free carbon or graphite has enormous effects on the properties of cast iron are perfectly true, and I first strongly emphasised this point over 15 years ago.

The micrographs in figures 5 to 10 are also interesting, and particularly the fact that test bars cut from a liner gave almost the same results as the bar cast direct, which is not the usual experience.

It is somewhat surprising that the Brinell number in the neighbourhood of 212 could not be cut with a hack-saw, and quite recently I published the results of an investigation were *on the same analyses*, but from sections cast 1in., $\frac{3}{4}$in., $\frac{1}{2}$in. and $\frac{1}{4}$in. square the Brinell hardness numbers varied from 175 on the 1in. section to 289 on the $\frac{1}{4}$in. section. These results were confirmed.

The theory of sulphur-manganese balance versus silicon control is new, and it is pleasing to know that Mr. Young has come to the conclusion that the consideration of silicon, whilst assisting the iron founder, sometimes fails, the reason being that the physical properties of the iron as disclosed by the fracture have not been considered.

In this respect one of the best papers that has yet been published was by Guy R. Johnson, Membreville Furnaces (Iron and Steel Institute, 1898, Vol. 2, page 200). Mr. Johnson admits that his exhaustive tables are weakened in that only one iron, —*i.e.*, his own brand—was experimented with, but his tables are remarkable in that he has been able to vary the combined carbon, silicon, sulphur and phosphorus, keeping the other analyses practically constant. Amongst other things, his tables 1 and 5 show considerable variations in ratios of combined and free carbons *on the same silicon*, which, however, is explained by physics. His best results were condensed and quoted by me in 1906 before the West of Scotland Iron and Steel Institute, and are as follows:—

Highest Tensile Variable Element.	Si.	S.	P.	G.C.	C.C.	Lbs. per sq. in.
Combined Carbon	1·29	·053	·179	2·84	*·92*	35·950
Silicon	*1·27*	·07	·178	2·98	·85	29·050
Sulphur	1·23	*·141*	·202	2·96	·97	35·650
Phosphorus ...	1·06	·078	*·247*	2·97	·85	30·300

Bars 2 in. x 1 in. x 2 ft. Centres.

Highest Transverse— Variable Element.	Si.	S.	P.	G.C.	C.C.	Lbs.	Deflection.
Combined Carbon	1·21	·061	·174	2·95	*·93*	3·100	19
Silicon	*1·07*	·077	·183	3·07	·78	2·950	17
Sulphur	1·19	*·072*	·197	3·07	·80	3·050	18
Phosphorus ...	1·06	·078	*·247*	2·96	·82	2·850	18

Bars 1 in. x 1 in. x 12 in. Centres.

Highest Drop Test— Variable Element.	Si.	S.	P.	G.C.	C.C.	Drop Test.
Silicon	*1·01*	·77	·183	3·07	·77	10 blows
Sulphur	1·19	*·072*	·197	3·07	·80	11 ,,
Phosphorus ...	1·01	·075	*·150*	2·93	·82	10 ,,

Unfortunately, Mr. Johnson does not give the manganese contents. so that Mr. Young's theory of sulphur-manganese balance cannot be applied, but Mr. Johnson also gives tables showing the value of fracture as well as analyses. One value of Mr. Johnson's research, which covered a period of three years of observation, is that it shows the difficulty of controlling tests, etc., by chemical composition alone.

With regard to the theory that manganese neutralises sulphur, this was stated a few years ago, and I made many enquiries for proof, resulting in the reference back to the *statement* of one gentleman, on the neutralisation effect of sulphur by manganese. I have also consulted Dr. Moldenke and others, who agree that all the sulphur is not neutralised by manganese in the higher sulphur irons.

Before the I.B.F. at their Blackpool meeting in September, there was a paper given on the "Electric Furnace," the chief value for my purpose being that sulphur was reduced, and this was claimed to be the cause of the higher tests obtained. In support of my views that manganese does not neutralise all the sulphur in higher sulphur irons I refer to the research of Wilfred L. Stork on "Oxygen in Cast Iron in the Iron Age, 1906/1919," which research confirms Johnson's theory. In this paper Mr. Stork gives figures of sulphur analyses poured hot, and the reduction on boiling, following which he states:—

"Iron in the state of boiling gives the manganese and sulphur "the opportunity and the time to get together and form sul-"phide of manganese, which rises to the surface as slag."

With which view I am in agreement. Sulphide of manganese can only be formed in molten metal, which if kept in that state for a sufficient period rises to the slag. Some sulphide of manganese may be trapped in the cooling of the metal, and the remainder, as in high sulphur irons, remains as sulphide of iron.

With regard to castings for internal combustion engines, from one point of view I am sorry to be unable to agree with the author, that it is necessary to make the working parts of these in the cheapest possible way. There is a very great field for investigation and I regret it is not possible to publish the results of two recent investigations I have carried out on Diesel engine castings, but I have come to the conclusion that if suitable castings can be produced which will give a longer life than the cupola castings, although it may be a higher first cost, it will be cheaper in the end; after all final cost and efficiency is of greater importance than cheap first cost without efficiency.

In conclusion may I point out some apparently clerical errors in tables 1, 2 and 3.

(*a*) In the second table the maximum phosphorus found in three different hematites was ·60%, ·40% and·27%, but there is no *hematite* which contains such a high percentage of phosphorus, although a steel making "off-grade" which might well be suitable for foundry work might contain something under ·10%.

(*b*) There are few works who would *publish* any of their analyses as dead accurate, as it is well known that these vary considerably in silicon and sulphur contents on the same number, and in fact the silicon can vary in one cast from the blast furnace as much as ·50%. Because of this it is always customary to say *approximate analysis*, as dead true analysis cannot possibly be guaranteed from the blast furnace direct.

Finally, I do most heartily agree in principle with Mr. Young when he states:—

"Pig iron of standard element composition would solve "nearly all the difficulties of the jobbing foundry, and most "of the foundries doing important work."

Although I would put it in rather a different way, *i.e.*, *a proper understanding of the fracture and chemical composition of pig iron and the practical application of its use in the foundry would solve most of the founder's difficulties.*

Mr. Young: Mr. E. Adamson's contribution is particularly interesting in that it voices a certain school of thought, and as it is about the only truly metallurgical contribution I propose to answer it in full.

Mr. Adamson asks for the total carbon, graphite and combined carbon in each section of the propeller blade. The micrographs shown in Fig. 1 are typical of all propeller blades I have examined, but obviously the amounts of carbon will vary from blade to blade and also from section to section of each blade—it would be very misleading to quote any particular amounts, and, moreover, not in any way would it assist the argument.

I fail to perceive Mr. Adamson's point when he says that iron cast 1in. square gives a Brinell number of 175 and the same iron cast $\frac{1}{4}$in. square gives 289. It is common knowledge that if one casts a wedge-shaped piece of iron tapering from, say, 1in. section down to, say, $\frac{1}{4}$in. section, the iron at the thickest end of the wedge will be soft as compared with that towards the thinner end. The matter does not appear to have any bearing upon the phenomenon of an iron having a low Brinell and yet being uncuttable with a hacksaw.

Mr. Adamson also writes as follows:—"It is pleasing to know that Mr. Young has come to the conclusion that the consideration of silicon, whilst assisting the ironfounder, sometimes fails, the reason being that the physical properties of the iron as disclosed by the fracture have not been considered." I would point out that I never gave, or hinted at, any such reason, and moreover, I cannot endorse the reason as now given by Mr. Adamson. A consideration of "the physical properties of the iron as disclosed by the fracture" has not, up to the moment of writing, given any hopes that such consideration will help us out of our difficulties. Further, I have kept a constant watch upon cast iron as made by many foundries with nothing but "fracture" to guide them, and these observations have, without exception, led me to the belief that it is an untrustworthy guide.

Give a man a piece of cast iron about which piece he knows nothing, not even the casting thickness or cooling conditions, and you will find that his observations made from a study of its fracture will not be particularly useful. On broad lines the grading and choosing of pig iron by fracture may be valuable—on broad lines.

Mr. Adamson quotes at length the work of Mr. Johnson, and, once again, he (the author) fears that he is unable to see its bearing upon the present subject. The condensed results, as given by Mr. Adamson, depict apparently a series of tests of iron of very high carbon-content, namely 3·73 to 3·93%, and very low phosphorus, namely 0·15 to 0·25%. In the first or "tensile" series there appears to be little of any interest save that the bar with the lowest graphitic carbon gives a tensile strength of about 3·08 tons per sq. inch higher than the bar with the highest graphite. Certainly in one bar the sulphur is 0·141%, but as no manganese is given one can pass no judgment.

In the second or "transverse" series there is little difference in composition and only 250 lbs. difference between the highest and lowest transverse test. Similar comment applies to the third series.

These three tables, as set out by Mr. Adamson, would appear to be most excellent evidence that tests can be controlled by chemical composition alone, but apparently Mr. Adamson desires to prove the direct opposite. He further says: "With regard to the theory that manganese neutralises sulphur, etc., etc." I wish it to be understood that these are Mr. Adamson's words and possess a meaning which does not appear in my paper. The paper was largely directed towards pointing out the beneficial effects to be obtained by balanced sulphur as against the bad effects to be obtained by unbalanced sulphur, no matter whether the sulphur be high or low in either case.

Speaking apparently of cupola-melted iron, Mr. Adamson goes on to state: "Some sulphide of manganese may be trapped in the cooling of the metal, and the remainder, as in high sulphur irons, remains as sulphide of iron." It seems to me that Mr. Adamson would find it difficult to produce proof of this statement. Figs. 15, 16 and 17 are pictures of high-sulphur cast iron and, under the microscope, we have been unable to detect any other sulphides than those shown in these micrographs and sulphur-print.

Speaking of castings for internal combustion engines, Mr. Adamson says:—"I am sorry to be unable to agree with the author that it is necessary to make the working parts of these in the cheapest possible way—if suitable castings can be produced which will give a longer life than the cupola castings although it may be a higher first cost it will be cheaper in the end." I think that nothing in the paper can give anyone justification for thinking I advised the making of inferior castings in an inferior manner. On the contrary it is that superior castings should be made in the cheapest possible way; if it means a higher first cost we shall have to submit to it. The point of my argument was that it has not yet been proved that the cupola cannot produce what is required, and that it ought to be proved before we commit ourselves to a more expensive process; this, however, was made perfectly clear in the paper itself.

I am pleased to have Mr. Adamson's confirmation that dead true analyses cannot be guaranteed from the blast furnace direct, and note with interest his statement that "in fact the silicon can vary in one cast from the blast furnace as much as 0·50%." If Mr. Adamson will refer to Tables I., II., III., IV. and V., he will discover that ironfounders are not interested *in the* 0·50% *variation in silicon*, which he says can happen in one cast, *but in the immensely greater and more important variations that can, and do, happen in one consignment*, and the still greater ones that happen over a number of consignments over a number of years.

In conclusion I thank Mr. Adamson for contributing a metallurgical comment upon the paper, the value of which, I feel sure, would have been enhanced had there been more communications of similar nature.

Mr. Young adds that since forwarding the above, he has had a conversation with Mr. Adamson, and he feels it is only fair to make some further additions to his reply.

Whilst having many different opinions to those held by Mr. Adamson there is one point regarding the sulphur-manganese balance which he misread in the paper and which influenced his comments. Under certain conditions sulphur and manganese form a slag which segregates into globules and gravitates towards the surface of the molten metal. These globules sometimes get entrapped in castings and cause serious defects. Mr. Adamson apparently believed that he dealt with these globules and with this phenomenon in his paper, but such is not the case.

Looking at Fig. 15 it will be seen that the sulphur print shows a distribution of sulphide "globules" remarkable for its uniformity and lack of segregation, while Figs. 16 and 17 show several of these same "globules" under high magnification—the term "globule" being used with reservation. It will be noticed that the paper does *not* state that these "globules" are manganese-sulphide, though they are probably sulphides containing manganese.

Another interesting point is that, so far as the author has had time to observe, very similar pictures of similar "globules" are to be obtained from low or high sulphur cast irons, containing, say, below 0·060% sulphur and above 0·200% sulphur respectively—the manganese content being from 0·4 to 0·5% in each case.

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Weather at Sea, with special reference to Clouds and Waves.

Illustrated by Cinema Films and Lantern Slides.

LECTURE BY SIR DAVID WILSON-BARKER. R.D., R.N.R.

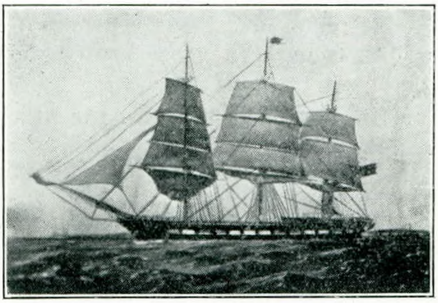
(Past President Royal Metrological Society).

On Tuesday, January 17, 1922.

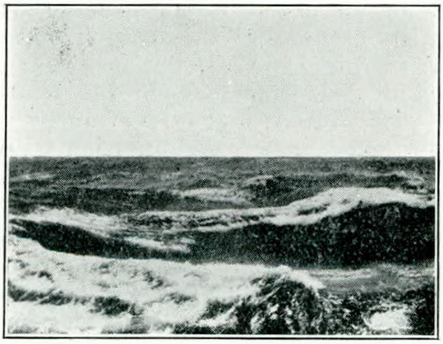
CHAIRMAN: MR. J. SHANKS (Vice-President).

The subject I am to talk about this evening is an ever-interesting, though dry (especially this past year) subject, and I should not have ventured to do so but for the fact that sailing ships are absolutely dependent upon the weather for their transport from port to port, and even steamers at times suffer greatly from its buffetings. In connection with the weather I shall deal specially with two subjects, clouds and waves, to which I have devoted particular attention.

There is little doubt in my mind but that all weather conditions were started by the difference of temperature between the Poles and the Equator, amounting as it does to some 120°F. This sets up great movements in the atmosphere and in the sea, which become whirls or partial whirls by the revolution of the earth acting on the currents as they move polewards, on account of the different speeds at which the earth moves at the various parallels of latitude. For instance the speed of a particle at the Equator is about 1,000 miles per hour, at the Poles 0—so that this has even to be taken into consideration when firing the modern long range gun; also the temperature and barometer—a particle of air moving poleward from the Equator is constantly crossing portions of the earth's surface, moving at a slower rate, and *vice versa*, a particle of air moving Equatorwards from the Poles. This tends to form gigantic whirls, which would be regular in shape, were it not for the irregularity of the land surface, which introduces a very disturbing element. Still, over the sea surface we find portions of these whirls have been able to retain their hold—another important factor, the diminishing area as the Poles are approached, so that at the 30° parallel of latitude half the hemisphere is reached. The most important productions of these whirls are the areas of high barometric pressure we find over the oceans and over the land. Those over the oceans are approximately permanent, those over the land

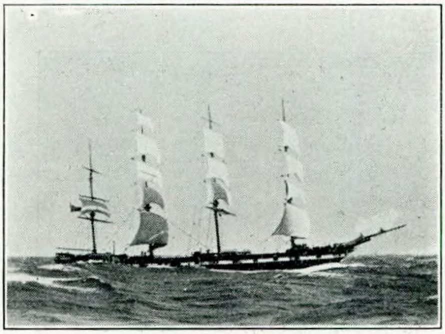


The "Windsor Castle."



Rough Sea off Cape Horn.

change with summer and winter. Here we only consider those over the oceans and we find that they are a great controlling factor in ocean weather. The actual weight of these enormous masses of air on the seas must have some effect on the level of the oceans, a fact which has been too little considered.



Running—Easting Down.

As you all know, the weight of the atmosphere represents about 15 lbs. to the square inch (actually 14·73 sea level) so that a man of ordinary size supports a weight of about 14 tons.

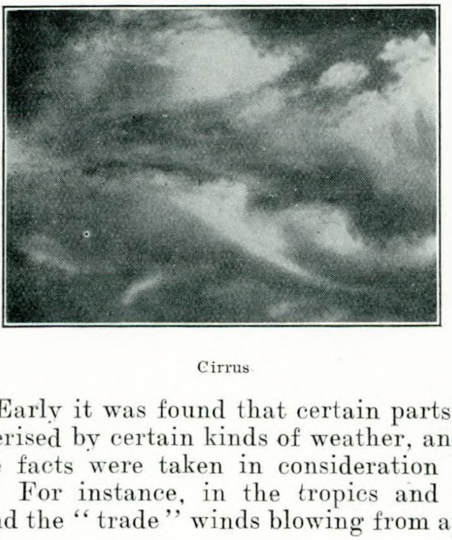
High Sea off Cape of Good Hope.

The weight of air in this room is about 1,700 lbs. The air is made up chiefly of the two gases, oxygen and nitrogen, as a mixture, the nitrogen appearing to have the effect of a diluent on the very active oxygen. In addition to these gases watery vapour and carbonic acid form small but appreciable parts, and there are traces of quite a number of other gases, indeed it is difficult to imagine that the air could be without traces of every kind of gas.

One of the most important weather factors is the watery vapour in the air, and numbers of different devices are used for endeavouring to determine this amount, but it is a difficult problem.

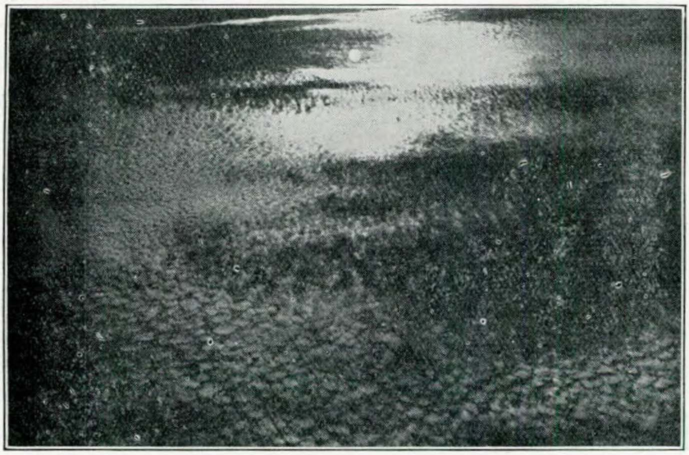
Waterspout off Genoa

The ordinary height of the atmosphere is about six to seven miles, but traces of it have been found to a height of 300 miles. I do not propose to discuss this difficult question here as it has no immediate bearing on the very general matters we are talking about. Early it was found that certain parts of the world were characterised by certain kinds of weather, and full advantage of these facts were taken in consideration by the early navigators. For instance, in the tropics and semi-tropical regions we find the "trade" winds blowing from approximately



Cirrus

N.E. in the northern hemisphere, and from S.E. in the southern hemisphere; on the polar side of these regions we find a stormy belt characterised by gales in which Westerly winds predominate. But here the effect of the continents become visible, for in the Indian Ocean the great heat in the Northern summer of the Asiatic Continent does away with the North-Easterly trade wind and draws up to the North the South-Easterly trade wind as a South-Westerly (deflection due to rotation of earth) wind, called a " monsoon "; the same effects in a modified form are found in the East Indian Archipelago, on the West Coast of Africa by the Gulf of Guinea, and on the Pacific side of the Isthmas of Panama. We find also in the land and sea breezes, so prevalent in some places, as the day and night wind are due to similar causes. The large areas of high pressure have a great bearing on these questions of sub-permanent winds, and their presence at certain portions of the ocean's surface near the position of the half hemisphere spoken of before is not without significance.



Cirro Cumulus.

*Fogs are another important factor in weather at sea. In some regions, as for instance, off Newfoundland and the Falkland Islands, they are nearly always present, other places, like the coast of England, they occur at times, when the conditions,

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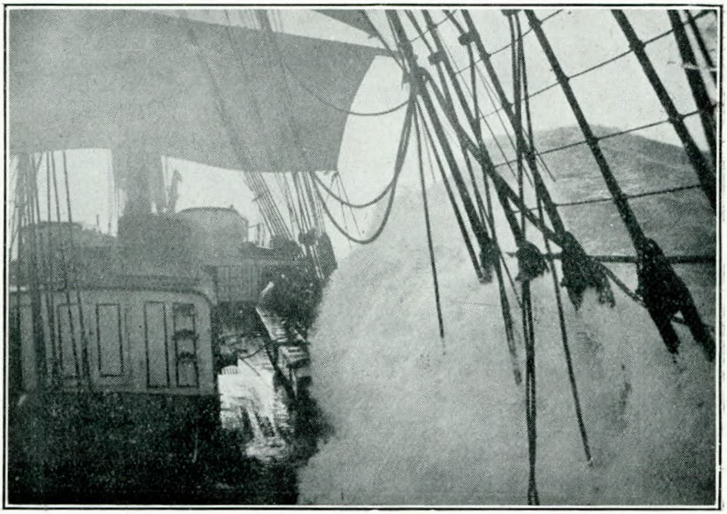
[*] Fog is a thick opaque mass and characteristic of calm weather; a mist may accompany much wind and is not so opaque or limited in extent.

generally warm sea and cold air, are favourable. Such conditions are not found in the tropics, but as the Poles are approached fogs are found in increasing numbers. The places where constant fogs are found, such as the places mentioned above, are situated in areas washed by the warm equatorial currents into which obtrude cold polar ones.



Shipping a Sea—Ship "EUTERPE."

While storms are found chiefly in the areas on the polar sides of the trade winds, certain parts of the ocean world are the areas of very violent storms known as hurricanes or cyclones. Such parts are the West Indies, Bay of Bengal, China Seas, Mauritius and about Samoa. It is quite unknown how these storms are generated, but when once formed they follow certain routes with a fury and destructiveness that is extraordinary. Ships have been blown for miles inland, aided, no doubt, by the temporary rise of the sea, and to the wonder of everyone when the storm had subsided. They move on these routes with considerable rapidity, and in the old sailing ship days it was the anxious duty of the captain of the ship, caught in one of these storms so to handle her as to avoid being dismasted or sunk. Even in a full powered steamer it is necessary to study these storms and be prepared to take such action as may avoid placing the ship in the most dangerous portion of the storm. Some two years ago there was an instance of this in the Arabian Sea. Two powerful steamers, quite close together, got into a cyclone, one ship was handled so well that she came out comfortably, the other was not so handled, and landed her owners into a very considerable expense for repairs.*

Cyclones of a minor area, but still very violent, are called tornadoes, and are found in the vicinity of land. These storms are met with particularly on the West Coast of Africa. Then there is the storm known as the pampero, which blows at times with great violence off the River Plate in the South Atlantic. There we were caught in the *Windsor Castle*, and the result was loss of mainmast close to deck, mizen topmast, starboard bulwarks and two boats and other minor damage at 7 a.m., September 17th, 1874. With much difficulty the wrecks of the masts were cut away, the starboard side of the ship over which the spars were lying being under water. At 2 a.m. the next morning the foretopmast was carried away, and the cock-billed foreyard broke through the fore stay and lodged itself in the trestle trees. All this time the sea was making clean breaches over the main deck, and it was impossible to get on to the forecastle. The ship was also leaking badly, and men had to be lashed at the pumps to keep her free of water. A warp was attached to the wreck of the foretopmast to make a sea anchor, and this eventually brought the ship head up to the sea after 72 hours of severe battering about, and after some 200 tons of cargo had been thrown overboard. One had always to be prepared for this sort of thing in a sailing ship. The regular storms such as one experiences in these latitudes can be very severe at times, but damage is frequently done by sudden squalls, and in the passage out to Australia in the high Southern latitudes, we had such an experience in losing the mizen topmast and main t'gallant mast. I have seen a large 30ft. boat which was lying bottom up alongside another one taken up by the wind in a severe squall turned completely over and thrown over the other boat.

While tornadoes are generally accompanied by thunder, lightning and very heavy rain, thunder and lightning are not so common at sea as on land, and it is comparatively rare that a ship is struck by lightning. In connection with this I may mention a rare but interesting phenomena, St. Elmo's fires. I have seen them twice, both times in very bad weather. They appear as greenish flickering lights on the tops of masts, and

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* Wireless reports can now be of great assistance to Navigators with regard to these storms.

at the yard arms, and only last for a short time. It is probably some form of electrical discharge.

Waterspouts are remarkable phenomena and are often seen. They are very curious and interesting. In the old days they seem to have been a danger to ships, and it was customary to destroy them by gun-fire. I have seen as many as six at one time, and in one case a minute one passed so close to the ship that I was able to put my hand out into it.

It was never realised until a curious thing happened during the war, that the density of the water could have such a remarkable effect on a vessel. A submarine was going down a certain channel when she was suddenly carried to the surface and ashore. When the density of the water was examined the reason for this curious disaster at once became apparent as it was found that the density of the water in this channel varied greatly and that the lines of variation were very close together on one side of the channel. This the submarine suddenly struck with the above result.

Owing to the openness of the horizon at sea, clouds come in for a good deal of attention, especially as it was always realised that they were of vital importance as aids to forecasting and also they were constantly objects of much beauty. There are two main divisions of clouds (*a*) Cumulus or heap clouds, and (*b*) Stratus or layer clouds; the former type, as its name implies, is of a massive structure with a low level base, but the upper part is often projected to a great height. The latter is a flat layer-like cloud of comparatively speaking no great vertical thickness—except in the case of Nimbus the cloud of continual rain. These two main types are broken up into many varieties, which I will describe in the pictures. Cirrus is a high variety of stratus composed of ice crystals, and is the chief cloud for forecasting. (Here came pictures of the various kinds of clouds with description. I will describe what happens when a storm passes over us in these latitudes.) Altering S. to N. the same effects take place in a similar latitude of the Southern hemisphere. Tides can be affected by the weather, as evidenced by the high tides in the Thames now and then, and the recent high tide at Hull.

Very beautiful effects are sometimes seen when rings and interlacing rings of coloured light form round the sun or moon in the Cirriform or high Stratus clouds. Sometimes the effects are brilliant, showing all the colours of the spectrum. Then there are false suns, difficult to distinguish from the real sun; nearly all these effects are associated with bad weather. Sometimes a wonderful pillar of light extends upwards from the setting sun. Another lovely effect is seen at times when carefully looked for in the rays that arise sometimes from the setting sun, and spread nearly all over the sky. The effect is also sometimes seen before the sun rises. Sunrises and sunsets are seen to perfection at sea, and there is also the curious effect of the brilliant green flash which is sometimes seen just as the last glimmer of the sun disappears below a clear horizon.

Clouds of the high Stratus variety, known as Cirro-cumulus, sometimes display lovely colours in the vicinity of the sun and seem always to be the precursor of bad weather. We have much yet to learn about the weather. Wireless telegraphy has opened up a new field of exploration in the atmosphere which may result in some remarkable discoveries, for it shows curious movements going on in the atmosphere about which we at present know nothing.

Then there is the question of the rate with which we are rushing through space, at one time we may be going three miles a second, at another time 19 miles a second; may it not be possible that this would account for some of the vagaries we experience?

The effect of the wind on the surface of the sea is to raise the surface into ripples, wavelets, and then waves. The wind effect does not appear to penetrate to a greater depth than 100 fathoms, below that, except for currents, the water seems to be still. Not only are waves raised by the friction of the wind, but also by a certain amount of drawing up action by the air passing over the crests and depressing action in the troughs.

COMPARISON OF WIND DISTURBANCE WITH WAVE ELEVATION.*

	Desbois.	Paris.	D. Wilson-Barker.	Mean.
	Feet.	Feet.	Feet.	Feet.
Hurricane ...	28·5	25·5	28	27·3
Strong Gale ...	20·6	16·5	23	20·0
Gale	15·4	—	14	14·7
Strong Breeze ...	10·8	—	8	9·4

* These results were arrived at independently and from purely practical observations.

From the Design and Construction of Ships, by Sir J. H. Biles, L.L.D. Vol. I., p. 318 (published by C. Griffin & Co.).

The height of waves is measured from trough to crest, and their length from wave crest to wave crest or from trough to trough. That waves have to be considered in the large powerful steamers was shown the other day when Capt. Sir Bertram Hayes described his great ship, *The Olympia*, as "tossed about like a leaf."

I have endeavoured in this short address to bring before you some idea of the weather conditions at sea. Possibly no class of men, except the modern airmen, see so much of the weather, as they live in it all the time. It has often struck me when up aloft at night time assisting to reef or furl the sails, with the ship rolling from side to side so that every roll one was suspended over the sea, the deck-outline of the ship clearly defined by the foam of the sea and the phosphorescence, what a remarkable sight it was and one never to be forgotten.

We have discussed the salient facts of weather at sea, the localities of storms, fogs, etc., the wonders and beauties of the clouds and their value as prognostics, and then we spoke of the varied disturbance of the sea which results in waves. It helps one to understand better the account I had the privilege of giving you the other day of the social life and the work and the play of the sailor.

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The Chairman commented on the lecture, to which we had listened with pleasure, added to by the excellent views, which aroused memories of seafaring experiences. Sir David has evidently used the camera with advantage in collecting the photographs he had shown, and his observations upon these were very interesting, so much so that his next lecture would be looked forward to with pleasing expectation.

Mr. J. R. Ruthven proposed a vote of thanks to the lecturer, which Mr. H. C. Matheson and Mr. Wm. McLaren cordially supported. A vote of thanks to the chairman closed the proceedings.

We were greatly indebted to the courtesy of Messrs. Pathé Frères Cinema, Ltd., for kindly granting the loan of one of their cinema machines to operate the films showing the *Worcester* cadets in the various stages of drill, including "abandon ship." The same machine served the purpose of placing the lantern slides on the screen, this was a great convenience with saving of time, and our thanks are accorded to Mr. Evans, the representative of Messrs. Pathé Frères, for his kindness and help in the matter.

The Problem of Grey Iron Castings.

ADJOURNED DISCUSSION.

January 24, 1922.

CHAIRMAN: MR. F. M. TIMPSON (Member of Council).

The CHAIRMAN: The lantern slides will be shown on the screen in order that Mr. Young may give an opportunity to those who were unable to be present at the reading of his paper in December to study, along with descriptive comments.

Mr. YOUNG: Among the points to be emphasised are the great difficulty in getting a test bar which truly represents the casting from which it was taken. Also in most cases where bad castings have been produced the cause has been unbalanced sulphur, and by controlling the proportions of sulphur and manganese, much better results may be obtained.

The CHAIRMAN: The subject is now open for discussion. Mr. Young's paper has come at a time when engineers are all looking for more light on foundry problems particularly as regards the use of cast iron in both super-heated steam and oil engine practice. We are fortunate in having the Author present to deal with questions which may arise in the discussion which promises to yield some useful information and maintain the value of the Transactions to the general membership.

Mr. W. McLAREN: I thank the Author for having come so far a second time in order to enable his subject to be more thoroughly discussed. It may be noted with satisfaction that at the present time many firms are demanding careful analyses of both the pig iron used and the castings produced in their foundries. As far back as 1876 experiments had proved the unreliability of cast iron, and even to-day there remains a great deal of research work to be carried out before the right quality of castings is produced to meet the demands of internal combustion engines, and the high temperatures generated in the cylinders. I think the iron ores should be examined and graded to find out the best for various purposes.

Mr. FAULKNER (Hon. Secretary, London Branch Inst. of British Foundrymen): I thank the Institute for inviting our members to be present as the paper is one of peculiar interest to us. It is a very pessimistic paper, yet we find that present-day research is advancing scientific control in the foundry to a very material extent, although perhaps not so rapidly as desirable. I have pleasure in making appreciative reference to the closely agreeing results obtained in the foundry with which Mr. Young is associated, as shown by Table VI., and wish to know more of the methods by which Mr. Young achieved those results. As regards the elements of uncertainty with which foundrymen have to contend, I may mention that on January 5th, Mr. C. M. Gill, of the South Metropolitan Gas Company, pointed out in a paper before the Institution of Mechanical Engineers, that the length of a firebrick may vary half-an-inch in length and a quarter in breadth and thickness. If special sections vary similarly, cupola troubles, accompanied by metal difficulties can be expected. Mr. Young's opinion as to whether the cause of the white hard spots showing in the structure of a casting which has been brought here this evening can be ascribed to unbalanced sulphur. It is by no means a freak, but a casting such as is being frequently encountered in the foundry. I do not think that the appearance of internal white spots are due to unbalanced sulphur, as Dr. Osann studied a case where the sulphur was 0·10 and the manganese 0·80 per cent., which latter is more than sufficient to balance 0·10 per cent. of sulphur.

Mr. Wesley Lambert, M.I.Mar.E. (Vice-President, London Branch Inst. of British Foundrymen): On behalf of foundry metallurgists of whom I am one, I thank Mr. Young for his paper. I was in complete agreement with everything the Author has stated in relation to the balancing of the sulphur and manganese contents in a cast iron. Sulphur *per se* may be a detrimental element in a cast iron. Sulphur combines very readily with iron, forming sulphide of iron, a compound having little or no strength. The original percentage of sulphur in pig-iron and scrap charge, as introduced into the cupola, is not reduced by melting, but rather increased as a result of acquiring additional sulphur from the fuel. Strong cupola coke has a sulphur content seldom below 0·75%. Manganese by selective preference combines with sulphur and segregates out into more or less harmless pools, leaving the matrix or ground mass comparatively free from the deleterious effect of excess sulphur. Hence, as the Authur has stated, even iron having a somewhat higher sulphur content than considered desirable by many cupola workers, can be rendered into good serviceable iron providing that the correct percentage of manganese is present in the iron. I have studied the data given in Mr. Young's paper, and cannot quite reconcile the figure with results obtained in my own experience. It is not generally recognised that the effect of sulphur in keeping the carbon in a combined state is greater than the power of silicon in the opposite direction. I would like to ask the Author if, when he speaks of sulphur control, whether he refers to mixing by analysis of various brands of pig-iron, or the addition of rich manganese bearing alloys to the cupola charge, or the introduction of ferro-manganese to the molten metal in the ladle. Further, whether he favours the remelting of iron, that is to say, a preliminary melting together of suitable grades of pig metal, scrap, and ferro alloys to obtain a desired composition, with subsequent remelting for the actual casting. In the old days at Woolwich, when cannons were made of cast iron, that procedure was adopted, and I am inclined to think that only in this way will the future demand for high-class castings for internal combustion and high temperature engines be satisfied. I am wholeheartedly with the Author in his statement that in order to be able to raise the working temperatures and pressures of our engines, and to lighten their structure it will be necessary to know more about cast iron than we know to-day, and I support his statement that if in this country we can get a number of works chemists in different works to give the subject of cast iron more attention, much may be gained thereby. As Gore says in his book, scientific research is not supernatural, and I might venture to add, is not necessarily confined to university laboratories. No one has a greater admiration for much of the work done by our academic research chemists, but the study of the problems connected with the successful production of cast iron castings can only be accomplished by the works chemist and metallurgist. The influence of the mass cannot readily be diagnosed in the laboratory. By the influence of the mass I would instance the example of the variation in the composition and structure of the cast iron propeller cited by the author. I look forward with confidence to the progress which may be made as a result of the work of the British Cast Iron Research Association, especially in view of the fact that they are investigating their problems in actual works foundries. It is useless to attempt to draw practical working conclusions merely from laboratory research; data must be obtained from actual castings, weighing perhaps several tons. Some present here this evening may wonder why, after all these years of pig-iron production it is not possible to secure more uniform pig-iron from the makers. Well, as you all know, pig-iron is reduced from iron ores in a blast furnace, and the variations in the moisture content of the air may be anything from 4-11 grains of moisture per cubic foot of air on any one day. In a blast furnace of a capacity say of 260 tons per day of 24 hours, no less than 126 gallons of water per hour pass, in the form of moisture, into such a furnace. As the decomposition of this large quantity of acqueous vapour is only accomplished at the expense of heat, the varying conditions caused by the atmosphere alone will be readily appreciated. Dehydrating plants are, it is true, provided with some blast furnace installations, but the initial expense is very high and the upkeep costly. Such conditions due to varying atmospheric changes, coupled with the fact stated here some short time ago, namely, that grey cast iron in the molten state is capable of absorbing very many times its own volume of gas, and even in the solid form as we use it, has been known to occlude in itself as much as 340 times its own volume of gas, to say nothing of the variable percentages of carbon, manganese. silicon, sulphur, phosphorus, copper, arsenic, etc., one need hardly wonder at the lack of uniformity in cast iron results, but rather marvel that the cast iron castings are as reliable as their general use indicates. I would conclude by complimenting Mr. Young on the photomicrographs and detailed analyses which accompany the paper, and also on the excellent slides which have been thrown upon the screen this evening.

Mr. Slater (London Branch President, Inst. British Foundrymen): I was struck rather forcibly by the all-round confession by experts, whether practical men in the foundry or chemists, that they knew nothing about the science of casting iron. Referring to the advantages claimed for re-melting, I may give an instance from my own experience several years ago, when dealing with a consignment of pig-iron, which when broken had the appearance of being largely composed of graphitic flakes. The ordinary methods of mixing and melting were found to be unsatisfactory. I then tried melting in an oil-fired crucible, and found that the grain had closed up considerably. After re-melting by this process four times, a maximum strength of 14 tons tensile was obtained, the iron being afterwards turned into castings with excellent results. I mention this as one example of the foundryman obtaining the desired results by re-melting and thereby closing the grain of the castings. But what the iron picked up in this process of re-melting I am not sure about, and would like to know if the information is available.

Mr. J. H. Graves: The chief lesson I have learned from the paper is the need for a closer co-operation between the chemist and the engineer, particularly during the actual carrying out of research work, at which the engineer is seldom present. I think the Author's description of cast iron as unreliable, should be restricted to certain cases only, as for some purposes it is reliable enough. I do not agree that our leading technical institutions teach little about the production and properties of cast iron. Referring to an incident quoted by Mr. Young, I certainly think it extraordinary that a representative of a firm of pig-iron makers should be absolutely at a loss to say why—when questioned on the point—his particular brand of iron was excellent for Diesel engine castings.

Mr. Cleaver (Inst. B.F.): Can the Author give the reasons why the micro-structure at the various sections of the propeller shown in the photograph were different at each section. I would also like to be further informed as to the best proportions of sulphur and manganese. From several of the lists of figures given the ratio two of manganese to one of sulphur appeared to give fairly good results. I had thought previously that the best ratio was at least four of manganese to one of sulphur. I would like to know whether the strength of an iron casting is increased or reduced by repeated heating and what changes take place in their consistency. On studying Mr. Young's results, which are very commendable, I wonder whether in his firm's foundry shop scrap is used as a base, the pig-iron being used only to improve the metal, and in what proportion, as the pig-iron analyses are so valuable. Also can Mr. Young give any figures to prove that a silicon content of 1·7 per cent. gives a close-grained iron suitable for high pressures, in thicknesses varying from one to two inches. What silicon base would he recommend for such work?

Mr. H. G. Sommerfield (Inst. B.F.): In Mr. Young's paper, he particularly emphasised the truth of his remark that "to purchase an iron upon its published composition is to buy a pig in a poke." Instances, and they are not at all uncommon, had been shown of the rather extreme analytical variations experienced even in the same consignment of an ordinary graded iron. It is obvious, therefore, that pig-iron, which has a reputation for regularity and reliability, by virtue of its special selection, would offer more safeguards to the foundryman. I presume that in Table II. of the paper the percentages of silicon and sulphur, as set down, do not represent the findings in one and the same pig. As regards sulphur and manganese I do not think the former should be the bogey it is alleged to be. I can recall a locomotive cylinder which had been in constant use for twenty-three years, and had only once been rebored. When this was dismantled and broken up the analysis showed sulphur to be 0·219 per cent., phosphorus 0·905 per cent., manganese 0·4 per cent., and silicon 1·6 per cent. Sulphur had not therefore proved of much detriment in this casting, and indeed it seemed to be quite a common experience to find castings of a generation ago much superior as regards wearing qualities to castings of modern-day production.

The question of re-melting pig-iron must remain a very open one. It is well known that sulphur would be absorbed in the process, and if it were essential to keep this element low, re-melting should be avoided. Re-melting would reduce the silicon and increase density, and might in some instances be useful.

Referring to the question of the best iron for Diesel cylinders. I may cite the case of a Continental works where invariably English irons were preferred to the best Swedish charcoal qualities, even though the latter were low in phosphorus, and, generally speaking, regarded as very pure. The heat and fluidity imparted by a well-regulated percentage of phosphorus secured an appreciation for English irons over the sluggishness noted in the Swedish.

Mr. Hall (Inst. B.F.): I am in agreement with Mr. Young's statement that the foundryman is working in the dark, without the guidance which science affords to other trades. I wish Mr. Young had dealt more with the general run of castings for jobbing work. My experience is that when the engineer complains that castings supplied to him were hard and could not be machined, the foundryman retorts that it was due to the engineers' tools being faulty, but this satisfied nobody; what is wanted is exact knowledge of what occurs in the foundry processes so as to admit of the product being controlled. At present we only know when castings are good or bad by breaking and examining samples. Science must be brought into the foundry if the desired progress is to be secured.

Mr. Young: I have to express my thanks for the kind remarks which have been made. I think Mr. McLaren's idea is that chemists should deal with the iron ore rather than the pig iron as cast. I totally disagree with that idea; the ore is a natural product, and we have to buy pig-iron as it is sold, and make the best of it. Mr. McLaren has suggested that there had been a great deal of research carried out on cast iron. I have searched very thoroughly all available records on the subject, and have found very little in the nature of original research. I know of a recent instance where the secretary of a scientific society had been asked to name some book which would give many photographs of cast-iron, and after searching carefully he had failed to discover any such books.

Mr. Faulkner's question inferred that I had been able to obtain better iron than other people; that is not true, as there are other people getting good results, though they are few. I deplore the preservation by practical iron foundrymen of so-called "secrets," by which they are supposed to obtain good castings; there are no such secrets. I have sometimes found these secrets to be the contents of a very ancient note-book. Foundrymen, chemists and engineers should frankly admit that they know very little about the science of cast iron, then they would soon begin to make real advances in that knowledge by working loyally together with a common aim. My own results are simply the outcome of hard work, and that is all that is necessary. Frequently the chemist is too much under the direction of the engineer; that is wrong, the chemist should be given a free hand, and if he does not get results he can be dispensed with, and another man tried. A remark was made at the previous meeting about England being full of "tame chemists," to some extent I agree; a chemist in works needs to be a live man or he is useless.

I appreciate Mr. Lambert's remarks as those of a chemist and metallurgist. We want to make it clear that the foundryman cannot by himself effect the desired control of sulphur, manganese, silicon, etc., but he must work in conjunction with the chemist to that end. Sulphur affects to an important extent castings required to withstand high temperatures. Mr. Lambert spoke of the influence of the many other elements in cast iron, but I think it is enough to attempt at present to study what influence the more common elements have on the iron, and we could pass on to oxygen and others when we understand the former.

Mr. Slater asked why the grain of cast iron is so closed up by remelting. This information is readily obtainable from the numerous works published on the subject, and I urge foundrymen to study more earnestly. The reason is that the proportions of silicon, carbon and manganese are lowered and that of sulphur raised by the remelting.

I regret Mr. Graves has not added the facts on which he based his remark that cast iron is not an unreliable metal. I have given reasons to prove my own statement that cast iron is unreliable; for example, the engineer's high safety factor irrespective of the strength of the iron. Also many castings are much heavier than they need be, simply because cast iron is unreliable. Again, in many cases steel castings are being used to-day instead of iron, for the same reason. As regards the teaching of the metallurgy of cast iron, I might mention the Newcastle district, where there is little or no teaching given on this subject. Students come from the colleges knowing practically nothing about the metals of commerce; they are not even taught that there is much to know.

Mr. Cleaver asked whether the differences in the sections of the propeller blade as shown in the photographs were due to sulphur. They were not, but were merely due to the different thicknesses and environments of parts of the casting and the consequent different rates of cooling. If test bars were made from the same metal, one 1 in. and the other 2 in. in thickness, they would give different results. The reasons are explained in the paper. In reply to the question as to whether the best ratio of sulphur to manganese is one to four, I do not know; that is one of the points we have to determine. As to how repeated heating and cooling of iron weaken the casting, research has been carried out in the matter and can be found in scientific journals. Mr. Cleaver also asked whether one could guarantee getting good castings by means of silicon control. That is possible, if the foundryman can control the silicon and keep the other constituents right at the same time. The foundryman cannot attempt sulphur control without the aid of the chemist, and consequently would do better to leave it alone and run on low-sulphur irons.

Mr. Lambert asked if I use ferro-manganese. The answer is that if one requires more manganese the only satisfactory way to get it is by using pig iron of higher manganese content; on the other hand, when melting steel in the cupola, it would be advisable to add some ferro-manganese to the ladle—this is exceedingly common and well-known practice.

Mr. Sommerfield regretted that I had not said much about ordinary commercial work. He was under a misapprehension, for most of the paper dealt with ordinary commercial work.—I wish to correct any impression that the paper deals exclusively with high-class castings.

Referring to the bad casting which has been brought forward this evening, it is plain what was the matter with it, but to name the cause is another question. I will be pleased to examine and report on it if the maker of it will tell me how he made it.

The CHAIRMAN: I have, before closing, to express satisfaction with the excellent opportunity we have had for the discussion, reminding those present that Dr. J. T. Milton, Past President, gave a very interesting paper on the subject of metals, dealing with the progress of research in connection with marine engineering materials, including cast iron. We congratulate ourselves on having had such an able authority to lecture to us at a time when it is becoming so necessary to acquire definite knowledge of this important subject.

Mr. GEO. ADAMS: I have pleasure in proposing a vote of thanks to Mr. Young. I think we all agree that he has got down to the bedrock of the subject in his excellent paper. That paper, backed as it is by Mr. Young's practical experience, provides much food for thought, and certainly shows the importance of scientific research. Such research is called for to-day in every trade in which this country is concerned. By means of such research our competitors on the Continent have captured trade which should have come to us. He contrasted the inadequate extensions which have been made to foundries during the war, with the extension of machine shops. Since the war there has been an even greater neglect of the foundries, owing to the shortage of money which might otherwise have been spent on improvements. The country must endeavour to remove the condition of stagnation as regards knowledge in the foundry; the present scanty store of knowledge has been based entirely on practice and rule of thumb. I am rather anxious to know how the small foundries will manage in the future, I refer to those firms who would be unable to afford to have a chemist on their staff. The difficulty would be lessened if the foundrymen themselves acquired more scientific knowledge, as Mr. Young has suggested, by reading as much as possible on the subject from books and lectures. The only firms to-day who can be relied upon to supply machinery or materials to strict specifications are those who base their methods on scientific principles. That is abundantly evident to members of the Institute from their experience with the machinery of vessels turned out by various firms. Mr. Young's paper is so full of useful knowledge that we could go on for a long time with the discussion. Coupled with this vote of thanks to Mr. Young I would like to thank those who have taken part in the discussion and to the lantern operator for his attention.

Mr. MAYOR seconded the vote, which was carried with acclamation.

Mr. YOUNG: I thank you for your vote of thanks and wish to make it quite clear that the paper is in no sense directed against the foundryman. I consider that the foundry has been starved in the past, while the education of the foundryman has been utterly neglected. In the past an engineer would readily spend several thousand pounds on plant for the machine shop if he thought it would increase the efficiency of that department, but he would hesitate before he would spend as many pence on better equipment for the foundry. I think it wonderful that the foundryman has got as far as he has, in spite of the lack of facilities, encouragement, and finance.

CONTRIBUTED BY CORRESPONDENCE.

Mr. H. J. YOUNG: It will be remembered that Mr. George Hall brought up the question of a defective casting, produced at the meeting, and wanted to know the reason of its mysterious failure.

The casting in question is a small bedplate, weighing about two cwts., and of which the sections vary between $\frac{5}{8}$ths inch and about $\frac{1}{4}$ inch. The trouble consists of what has been described elsewhere as "internal chill," namely, some of the metal in the centre of the body of the casting is white or nearly so.

The composition of the casting is as follows:—

	CARBON.						
	Combined.	Free.	Total.	Sil.	Phos.	Sulph.	Mang.
Grey part...	0·56	2·39	2·95	2·24	1·53	0·135	0·39
White part	1·97	0·95	2·92	2·23	1·52	0·144	0·39

Readers will have noticed in the *Foundry Trade Journal*, dated February 2nd, a long article upon the "internal chill" in grey iron castings and an investigation upon same by Mr. W. H. Poole. In every case quoted by Mr. Poole the sulphur-manganese balance is at fault, and the article says "Mr. Poole has successfully overcome this trouble by increasing the manganese content in the mixture." The Author's paper says as follows:—"Practical men know only too well the metal they describe as 'hard iron'—metal possessing every undesirable property, including weakness and brittleness . . . . the 'hard iron,' the *bête noir* of foundries and of engineers is a product of ignorance or of misfortune—foundries have ever been prone to sudden mysterious spasms of bad metal or bad castings—in every such case in the Author's experience the iron has always suffered from inadequately-balanced sulphur—no matter what the quantity of sulphur, that of manganese must be more than sufficient to balance it—if you put 'hard' unbalanced-sulphur iron into an intricate casting then that casting will be extremely likely to fail, possibly a few minutes after the metal enters the mould, and in any case the metal would be poor and brittle and have bad machining properties."

The Author quotes the above extracts from his own paper in order to prepare the way for his opinion upon the case of this defective bedplate casting sent by Mr. Hall.

In ordinary foundry work a sulphur content of 0·144% together with a manganese content of 0·39% in the finished casting would appear to the Author to be amounts bordering on the danger zone, but not in themselves dangerous. It would seem to him, however, that while this may apply to irons containing carbon about 3·3% (or more) and phosphorus about 1·2% (or less) the same does not equally apply to irons, particularly if poured at a low temperature, containing carbon about 3·1% (or less), and phosphorus about 1·4% (or more). He would think that a wrong sulphur-manganese balance is even more fatal to low-carbon-high-phosphorus irons and that it takes even more manganese to balance any one particular amount of sulphur than in the case of ordinary foundry irons.

Mr. Hall's defective casting was made from crucible-melted metal and therefore no question of cupola practice comes into consideration.

The Author recommends Mr. Hall to do two things, firstly, to raise the manganese content in his mixture and, secondly, to investigate from whence arises the very undesirable low carbon, high phosphorus and high sulphur content of this casting. In Mr. Hall's case, where crucible-melting is the practice, it would not appear difficult to eliminate the trouble once and for all, and the Author is communicating with Mr. Hall on the point.

The Mining of Tin Ore in China.

READ

October 11, 1921.

MR. SEMPLE'S REPLY.

The lay out of the plant is very similar to other mining plants, that is when the ore is brought down from the mines it is taken by elevator to the top floor where it enters the large ball mill, and there crushed to a 16 mesh, afterwards going to a secondary crusher where it is graded down to 100 mesh, from there it flows down shutes to jig concentraters where it receives its first washing, from there it flows down to the Wilfley shaking tables below, where it is further washed and graded, the tailings passing out to ponds for retreatment later on. As regards the percentage of tin obtained from the ore, there was some doubt raised as to being able to make standard tin from the ore obtained at Malaga, the result was that the Company brought out an expert metallurgist from America who spent over three months sampling and assaying the ore and he got some of the most marvellous results I ever saw; he showed me a sample he had taken from a large cast of tin bars he had made and after assaying them showed the high purity of 99%, and he proved that standard tin could be made from these ores. He made out a complete set of plans for a new lay-out of their smelting and refining plant, which I understand they are going to put in next year. The smelting furnaces at present are on the Siemens-Martin principle, six in number of ten tons capacity each, one gas generator supplying two furnaces. At present they only run two furnaces averaging about two casts a day, the native furnaces are of the beehive pattern and built of mud bricks and average two tons capacity, wood charcoal being used as fuel and the air blast hand driven; these furnaces work very well being easy to build and keep in repair.

The conditions at the mines for boys and men are practically the same, and ventilation most inadequate, being absolutely devoid of fans. Whether there are any mining laws relative to this province I don't know; there must be as there is a director of mines in Yunnanfu, but I have never seen them, the native methods of mining being used for centuries. However, the administration has all been changed this last year for the better, as many Chinese are educated in American mining colleges, and are quite alive to the existing conditions. I understand they contemplate sinking a shaft 1,000ft. deep to connect into the present mine tunnels at different levels, and also putting in a proper ventilating shaft with fans; also rebuilding all the housing quarters with well equipped hospitals and medical attendance which is much lacking at present. When these alterations are carried out it will be ideal for the miners, as they will then be able to work regular hours, and all the ore will be hoisted to the surface in mine cars and dumped into bins. At present, what causes the high mortality among the miners is coming out of these hot tunnels dripping with sweat, carrying their loads of ore, and being very thinly clad, the cold air simply catches them, and they develop lung trouble, which, if not checked in time turns into tuberculosis, and once they get that they only last about a week. They have no set hours of work at present, just simply so many loads of ore to bring up, the average being five, over and above that they get a bonus of ten cents a load. These loads for the men average 133lbs., and for boys about half that or according to their strength. So you can imagine what that means coming out of a tunnel 2,000ft. long, the floor having an incline of 45 degrees and the ore dump about half a mile from the mouth of the tunnel. As far as I understand their wages average from 50 cents. to two dollars a day, according to their time of service. All the miners are well fed, but that does not compensate for the hard conditions they live under at present.

In regard to British enterprise being lacking where German and American machinery are so much in evidence. In this Province prior to the outbreak of the great war, it was entirely under German influence, and no other nation had a look in, but the outbreak of war made the opportunity possible for other firms to come in, and this pumping contract was the result. No, I may say British enterprise is not lacking where they get the opportunity and a good man looking after it. The greatest hinderance British interests had during the last two years was the labour troubles at home when manufacturers could not give fixed prices and sure deliveries; on that account many fine orders were diverted to other sources. The people at home have got to realise that if Britain has to keep up her foreign trade they have to put their best efforts into their work and increase production so as to lower first costs and enable manufacturers to quote reasonable prices and give guarantees for sure deliveries. America is making a large bid for eastern trade, and not only so but encouraging Chinese students to go to their colleges and learn their ideals and methods, and each of these students returning becomes a potential ally to them. When you compare the number of students going to America and Britain it gives you an idea of what America is doing, especially when you know that British merchants were the pioneers in opening up the China trade, it makes one wonder why Britain is so lax in encouraging more students to come over. What we want is more schools and colleges in China endowed by Britain to spread British ideals and methods. I would suggest that any young man coming out East on business should know one foreign language, especially French, and if he is in China to study the language, as the Chinese are a fine people to deal with and once you command their respect it makes it much easier for you to do business.

So far as protection is concerned you are well enough looked after, and when conditions are bad in the Province the authorities won't let you go into the interior; the trouble is you can never anticipate anything when the bandits are around, as the trouble usually happens first, and they have been pretty active up in this region for the last two years. Several missionaries have been captured, but they got away again. I don't think that this bandit trouble will ever be put down until China gets a stable Government.

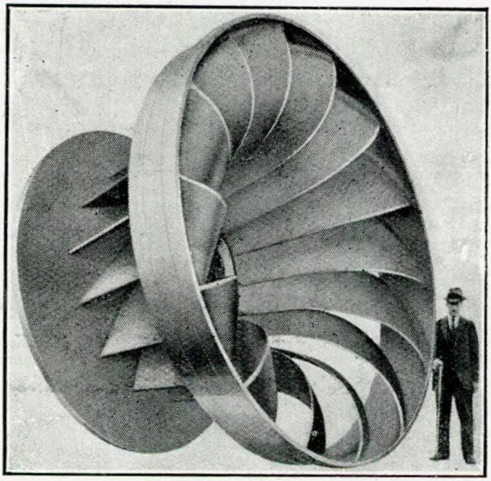
* * *

Notes.

The following paragraphs are culled from *The Iron and Coal Trades Review* of January 20th, and by the courtesy of the Editor, the illustration of the turbine casting is reproduced.

A Large and Intricate Steel Casting.—The annexed photograph of a large and intricate steel casting will be of interest to steel founders in that it represents the largest water turbine ever cast in one piece. Messrs. Boving and Company, Limited, of 56, Kingsway, London, W.C.2, the makers, state that the specification and principal dimensions are as follows:—7,700 b.h.p. runner for spiral-casing type water turbine acting under a water pressure of 31 ft. and running at a speed of 83 r.p.m. The outside diameters at the bottom and top are

13ft. 6in. and 11ft. respectively. The height from top to bottom is 8ft.



A Water Turbine Runner Casting.

A glance at the illustration will show that the moulding of this casting was in itself no easy task, and, when taking into consideration the large surface, the comparatively thin section of the metal, and the distance through which the metal had to be run, the difficulties of casting will be appreciated.

Low Temperature Distillation of Oil from Shale.—A young Scottish chemist, Mr. T. G. Ironside, has invented a process of low-temperature distillation of oil from shale, in which the powdered shale is pre-heated until it is just about to begin giving off vapours. It is then mixed in a retort with hot sand introduced at another point of the retort, by which means the shale is raised to the temperature necessary for complete carbonisation under low-temperature conditions, while the sand is just a shade hotter, and there is still sufficient heat present to distil off the volatiles. So far the process has been tested with a makeshift retort in South Africa, using the Waaihoek Cannel coal. No sign of clinkering of the material was observed in these tests.

Laboratory Work and Study.—In "The Marine Engineer and Naval Architect" for January, illustrations are given showing the laboratory at the works of the North Eastern Marine Engineering Co., Wallsend-on-Tyne. These are of special interest after Mr. Young's visit to the Institute to read his paper on December 13th and his subsequent visit on January 24th for the adjourned discussion. The descriptive article on the laboratory opens up more clearly many of the points dealt with in the paper and the discussion, and is thus a valuable addition to the whole subject.

Election of Members.

Members elected at a meeting of the Council held on 13th February, 1922:—

Members.

Charles Adamson, 155, Tudor Avenue, Bolton.

James Combes, 26, Holme Avenue, Walkerville, Newcastle-on-Tyne.

William Edward Drake, Marine Dept., G.W.R., Fishguard Harbour.

Alexander W. Eaglesome, 20, Strathcona Road, Wallasey, Cheshire.

William Leonard Earp, 96, Albacore Crescent, Lewisham, S.E.13.

George Thomas Lochead, 8, Beverley Road, Wavertree, Liverpool.

Frederick Thomas Norris, 108, London Road, Portsmouth.

George John Steinheil, 1, Lesney Park Road, Erith, Kent.

Stanley Burston Webb, 6, Kinfauns Road, Goodmayes, Essex.

William Frederick White, 46, Lonsdale Avenue, East Ham, E.

Associate Members.

Frederick Hampton Collins, 46, Valley Road, Anfield, Liverpool.

Patrick P. Mullins, 1, Bath Terrace, Glenbrook, Passage West, County Cork.

Associates.

Horace Aubrey Jarrett, H.M.S. *Inconstant*, *c/o* G.P.O., London.

James Petrie, 167, Great Western Road, Glasgow.

Graduates.

Joseph William Philip Barry, 106, Claude Road, Upton Manor, E.13.
Robert James Bond, The Nook, Medina Road, Grays, Essex.
Douglas William Freemantle, 102, Humber Road, London, S.E.3.
Charles Herbert Haines, 32, St. John's Road, East Ham, E.6.

Transfers :—

Associate-Member to Member.

William Semple, 1255, 13th Avenue West, Vancouver, B.C.
John Snell, Leaholme, Rancliffe Road, East Ham, E.
D. T. Summers, 21, Boston Road, E.6.

Graduate to Associate.

Charles Cory Suffield, 51, Arragon Gardens, Streatham, S.W.16.
M. W. Kurth, 258, High Street, Poplar, E.14.

JOHN ANDREW MANNELL (Member of Council, 1914-16).

It was with keen regret that the intimation of Mr. Mannell's death on December 28th, 1921, was received, and our sympathy was conveyed to his mother and family circle with a deep sense of the loss sustained by those who best knew his good qualities. Born at the Home Farm, Tehidy Park, Illogan, Cornwall, in September, 1870—the eldest son of Benjamin Mannell, the was educated at the Falmouth Grammar School and served his apprenticeship with Messrs. Townsend Hook. His first experience of sea life was in the S. Yacht *Paladin*, and after two seasons he joined the Aberdeen Star Line, and was appointed to the *Australasian* as refrigerating engineer in October, 1896. He was promoted to 4th Engineer in March, 1897, to 3rd in July, 1897, and to 2nd Engineer in July, 1899. He transferred to the *Damascus* as 2nd in October, 1901, promoted to Chief in July, 1902. In March, 1907, he was transferred to the *Marathon*, and in September, 1910, he was appointed Supt.-Engineer for the Company. Owing to ill-health he felt unable to continue his duties, and resigned in December, 1918.

Mr. Mannell took a keen interest in engineering, and besides being a member of the Institute of Marine Engineers, he was a member of The Institution of Naval Architects, The Institute of Metals, The Iron and Steel Institute, The N.E. Coast Institute of Engineers and Shipbuilders, The Wireless Society of London, Ice and Cold Storage Association, L'Association Internationale du Froid; he was also a Fellow of the Royal Society of Arts. In his earlier years he was an enthusiastic member of the Volunteers, and became a first-class shot, like his father before him, who was 1st Lieut. in the 5th Battery Artillery Volunteers, Cornwall.

LLOYD'S REGISTER SCHOLARSHIPS, STUDENT GRADUATE EXAMINATIONS AND ESSAY COMPETITIONS.

DEAR SIR,

As you may know of Junior Engineers or Apprentices whose qualifications should admit of them becoming candidates, your attention is directed to the following arrangements in connection with the above:—

Lloyd's Register Scholarships. These are three in number, one being available each year for three years at £100 per year. These are kindly bestowed by Lloyd's Register of Shipping.

Application should be made by intending candidates not later than March 10th, in order that arrangements may be made for the examination, which will be held on June 13th and 14th. The examination will be held simultaneously in various centres to suit the residences of candidates.

The regulations, with lists of subjects on which questions will be set, are as follows:—

I. The Scholarship is open for competition to candidates who are British subjects—this denotes all who are of British parentage in its Imperial sense—Graduates, Student Graduates or Associates of the Institute of Marine Engineers, Apprentices or Junior Engineers (not necessarily connected with the Institute), the age limit being from 18 to 23 at the date for entering the University. Preference will be given, in the event of nearly equal marks, to the candidate who acquits himself best at the subsequent oral examination before a special committee The successful candidate, if not already associated, must join the Institute in the grade for which he is qualified.

II. The Scholarship is intended to assist Marine Engineering Students. desirous of gaining higher attainments, to better qualify them for the duties of life in their chosen profession. An undertaking must be given by the successful candidate that he will continue his studies for the full period of the term, extending over three years, with a view to the B.Sc. degree.

III. The examination papers will be set from and based upon the following subjects and the award will only be given in the event of a candidate showing sufficiently good qualifications.

(*a*) Arithmetic, including the Metric System; Algebra to Quadratics.

(*b*) Elements of Statics, Dynamics, Thermodynamics, and Hydrostatics.

(*c*) Geometry, based on Books I., II., III. and IV.

(*d*) General Knowledge, English Composition.

(*e*) Theoretical Mechanics, Principles and Problems.

(*f*) Foreign Language—choice given to the candidate who is required to notify this on his application—Elementary Construction and Translation.

(*g*) Trigonometry, including Logarithms.

(*h*) Practical Engineering and Workshop Practice.

IV. The holder of the Scholarship must show satisfactory progress in his course of study at the termination of each session, in addition to which it is desirable that he should satisfy the committee as to the employment of his time during the recess.

V. The Scholarship, the conditions attached to it and the continuance of it, are entirely reserved in the hands of the Council, who may cease to continue it, or may alter the terms from time to time, on six months' notice prior to the date appointed for the examination.

VI. As the object of the Scholarship is to provide means for young engineers to add to their proficiency as Marine Engineers, only those are eligible who have served at least two years in a commercial engineering workshop, and until the time of application have been employed at engineering, either ashore, afloat, or at College, with the intention of entering upon the business of Marine Engineering, but not necessarily to remain a sea-going engineer.

VII. Subject to the approval of the Council, the successful candidate may choose the University or College most convenient to himself, but he must take all the classes in the recognised curriculum for engineering students at the University or College chosen.

Student Graduates.—Applications to sit at the examinations will be received till March 30th.

Dates and Subjects:—

Tuesday, May 2nd.—10-1, Theoretical Mechanics; 2-5, Heat and Heat Engines.

May 3rd.—10-1, Machine Construction and Drawing; 2-5, Applied Mechanics.

May 4th.—10-1, Mathematics, including Geometry; 2-5, English Language, including Composition.

May 5th.—10-1, Electrical Engineering.

Candidates (engineering apprentices and/or pupils after a 12 months Technical School course) may take all the subjects set for the pass, or for one or more days, and complete the requirements subsequently. An award or awards will be given in the event of the examination being passed with a high degree of credit.

Examination Fee, 2s. 6d.; Entrance Fee to the Institute, 7s. 6d.; Annual Subscription, 5s.

AWARDS.

Denny Gold Medal for the best paper read and discussed during the Session. Open to all members.

Sir Archibald Denny Award, value £4, open to sea-going Members only.

Two Stephen Awards, value £2 each, open to Associate Members and Associates.

John I. Jacob's Memorial Awards, value £2, open to Graduates and Student Graduates.

John I. Jacob's Memorial Open Competition Award, value £2, open to Graduates, Student Graduates and Apprentice Engineers eligible as Graduates.

Wm. Murdoch Memorial Award.

D. F. Robertson Award.

These awards will be granted to the writers of the best papers—if deemed of sufficient merit—as undernoted, or the amounts may be divided if the merits of the papers are such as to render a division desirable. They are also available for special awards.

Sir Archibald Denny Award for Sea-Going Members.—Subject, "Hints and Deductions from Practical Experience which may be useful towards improving ship and engine design. Reports upon Consumption of Coal or Oil; Water per I.H.P. per hour or similar comparison to show results."

Award for Associate Members.—"Application of Heat to obtain best Results in Maintenance of Steam and Circulation; comparative Merits of Fuels, Coal and Oil."

Award for Associates.—" Engine-Room Auxiliaries; their Services in respect to Economy and Safety."

Award for Graduates and Student Graduates.—" The Main Engine Shafting from and including the Crank Shaft; how lined off and fitted into a new vessel from the Propeller; also the Stern Tube, with detailed description of the latter."

Award for Open Competition.—The various types of Internal Combustion Engine now in service, with descriptive notes on the details and where economy is gained in construction or in working.

The Paper to be the certified sole work of the competitor, may consist of approximately 2,000 words, to be signed with a *nom-de-plume* (the name and address of the writer being also enclosed in a sealed envelope with the *nom-de-plume* written on the outside), and to be delivered addressed to " The Secretary, Institute of Marine Engineers, The Minories, Tower Hill, London, E., not later than October 1st. The wrapper containing the paper should be endorsed " Sea-going Member," " Associate Member," " Associate," " Graduate," or " Open Competition " as the case may be. Associates and Graduates are allowed the option of selecting the subject and competing in the class above them, but no candidate can compete for more than one award.

Yours faithfully,

JAS. ADAMSON,

Hon. Secretary.